AP

MONTHLY NOTEBOOK

cience and British Industry
Promise of a Stronger "Impact"
Operational Research
A Human Chimera evealed by Blood-grouping
Plant Chimeras
Agricultural Research

THE SIGNIFICANCE OF BACTERIAL POLYSACCHARIDES
Prof. M. Stacey

THE AGE OF STONEHENGE
I. W. Cornwall
Ph.D.

SOLAR ENERGY RESEARCH IN FRANCE
Maurice Goldsmith

THE BIOLOGY OF HUNTING SPIDERS
J. L. Cloudsley-Thompson
M.A, Ph.D, F.L.S.

SOCIAL ANIMALS
Derek Wragge Morley
M.A, F.L.S.

BOOKSHELF

FAR & NEAR

SCIENCE FOR ITS OWN SAKE
Sir Edward Appleton's Presidential Address to the British Association

The huge concave mirror at the Solar Energy Laboratory on Mont Louis

Discovery

SEPTEMBER 1953 1/6

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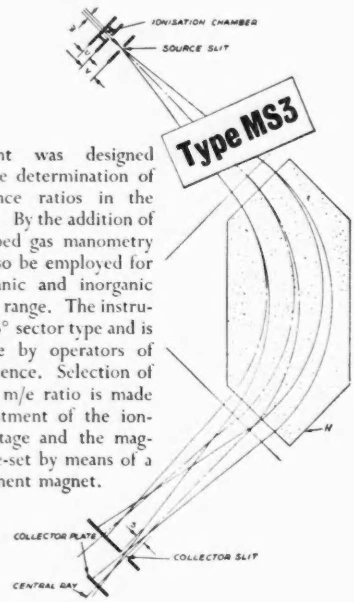

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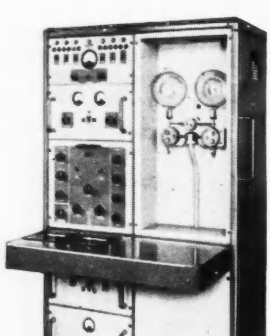

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Discovery

THE MAGAZINE OF SCIENTIFIC PROGRESS

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THE PROGRESS OF SCIENCE

SCIENCE AND BRITISH INDUSTRY

The sixth annual report of the Advisory Council on Scientific Policy takes the form of a report on "The Exploitation of Science by Industry". It arrives at four conclusions which are considered to show some ways in which industry might make more use of science in the interests of the country's economy. First, the number of scientists and technologists in industry should be greatly increased. Second, modern conditions call for increasing use of scientists and technically trained men on the boards of management in industry. Third, industry must put more emphasis on new methods and new products which depend on scientific and engineering skills. And last, the volume of investment in our manufacturing industry is too low, particularly in connexion with the development of new products and processes.

The debate on the report in the House of Commons failed to consider these points adequately. In our view, the outstanding point is the level of investment in industry. The other points are dependent variables to use the language of statistical analysis. A study of the figures shows that in those industries in which the investment per worker is highest, the boards of management have the highest proportion of technical men and devote the investment to the development of new ideas. In British industry in 1950 the average for the whole country was £60 per worker invested in new equipment (as compared with £180 in the U.S.A.); the oil and chemical industry spent nearly £200 per worker and the steel industry was second with the figure of £107 per worker. The record of these industries contradicts the assertion of the *Sunday Express*'s financial writer that scientists as directors spell doom. We would go further and maintain that high rates of capital investment are impossible where new methods have to be employed in the absence of an adequate proportion of technical men. This is most clearly borne out in the record of the National Coal Board.

Although the new capital is available, it has not been possible to implement to the full the investment programme which was planned and which was described as essential when the plan was first announced; the reason for this is stated categorically to be the lack of technical men to carry out the programme.

Since so much has been made of the expansion of technological education, two tendencies which have developed in the past academic year require some study. Firstly: difficulties are being met in placing this year's science and engineering graduates; it is the first time this has happened since the war, and the change is a significant one. The long queue of industrial talent scouts in front of every professor's door is likely soon to disappear, except perhaps where certain special subjects are involved. The other queue which seems to be dwindling is the queue of students seeking entry into the universities before the start of the new academic year. The students are not coming forward from the schools in the same quantity; there is less competition for places, and the universities no longer need to rely on excessively high qualifications in order to weed out their entry.

Perhaps two birds are at last coming home to roost. The schools may now be really feeling the difficulty of recruiting and keeping science masters on the pay which can be offered, and without adequate staffing the schools cannot maintain the output of science students who will continue the subject at the universities. The students may be revolting against the increasing length of science courses which keep them so long from earning when military service has also to be undertaken.

Perhaps the realities will be dealt with if the House of Lords comes to discuss this matter. Their Lordships usually show more concern for facts and a steadier vision than the Commons manage to produce. Of course it may be that they are only luckier because they have more scientists among their members.

PROMISE OF A STRONGER "IMPACT"

When Unesco first started the quarterly journal called *Impact* there was a good deal of interest in the venture, for there seemed to be a reasonably good chance that it could be developed into a first-rate journal in which the social relations of science could be discussed effectively and usefully. For a long time, however, *Impact* failed to make any substantial impact, mainly for reasons which were beyond the control of the original editor.

The journal now has a new editor, E. M. Friedwald, whose name will be familiar to most readers of DISCOVERY for the trenchant and provocative articles and reviews which he contributed to our columns between 1946 and 1950. Before the war Mr. Friedwald had won a considerable reputation for his skill as editor of one of the world's leading petroleum journals. The war brought him to London, where he worked from 1940 until 1950 when he returned to Paris to join Unesco's staff. Now he is in full command of *Impact*, and we are glad to see him once again occupying an editorial chair worthy of his talents. Providing he is given the scope to exercise those talents to the full, *Impact* can become as important a journal in its particular but wide field as, say, *The Bulletin of the Atomic Scientists* is in a somewhat similar but rather narrower field.

It must be added, however, that for the journal to become a real success its sales must be built up, and Unesco will have to do more than it has done in the past to make it widely known. *Impact* is meagrely advertised, and Unesco is inclined to be rather niggardly about the review copies to influential journals that might find occasion to mention *Impact*. But some imaginative exploitation, which need not cost a mint of money, could soon make up for past sins of omission in connexion with *Impact*.

The first issue produced since Mr. Friedwald was given full editorial control is the Summer 1952 number. Its general style and contents indicate that he is putting into effect a new policy. Instead of a miscellany of short and therefore rather scrappy articles, the new *Impact* contains three major articles, of about 5000 words apiece. One of them is a highly original article by Prof. Arnold Tustin, head of the Electrical Engineering Department of Birmingham University, on the subject of economic regulation through control-system engineering, in which he speculates about automatic regulators and controllers operating on the same sort of principle as electrical feed-back and stabilising an economic system. The Portuguese historian of science, Dr. Armando Cortesao, writes about Nautical Science and the Geographical Revolution.

R. T. Eddison, a Cambridge biologist who is now head of Departmental Research at the British Iron and Steel Research Association, has contributed a most interesting article on "Social Applications of Operational Research".

OPERATIONAL RESEARCH

"Operational Research" is a term which carries with it a somewhat magic and mysterious air, and it is still somewhat difficult to trace a succinct definition which adequately conveys its special character. But anyone who is still mystified by the term will find considerable enlightenment in Mr. Eddison's article.

It was the increased dependence of the Armed Services on scientific research and equipment during the last war which was largely responsible for the widespread development of operational research. The scientists were not content solely with developing new equipment but were also interested in seeing that it was used with the greatest effect. Their ideas about how this could be achieved were not trammelled by any hidebound approach or service tradition. They came fresh to the problem without any preconceived notions of what could (or should) or could not be done.

In working out the best ways of applying the machines they had created, the scientists extended their scientific techniques into the realm of operational tactics. Eventually someone coined the term 'operational research', which is on the way to becoming a household word. Today it covers a wide range of flexible, half empirical and experimental, and half theoretical techniques, for breaking down the day-to-day problems of the practical running of any organised body, whether it be a night fighter patrol, or army command, a factory, a harbour wharf, or the executive council of a large business organisation.

A simple example of the successful use of operational research in the war was the investigation of the effective use of depth charges. In the early stages of the last war all depth charges used by the British Navy were equipped with fuses set to detonate when at a depth of 100 feet. This was because at that depth, the containing pressure of the water surrounding the charges was just sufficient to cause the explosion to reach its maximum force. Although this fixed setting meant that the explosives in the depth charges were used with the maximum effect, it also meant that the anti-submarine attack could not be delivered until the submarine dived. The scientists decided the problem was one of probability—at what depth would the depth charge be most likely to 'find' a submarine within lethal range, granted the fact that once submerged the submarine could move on any course, both vertically and horizontally. The calculations showed that the decreasing of the 'detonation' depth of 35 feet would greatly increase the chances of a kill. Experiment proved them to be correct, and when the depth setting was reduced, the number of submarines sunk markedly increased.

Operational research has been described by Prof. Sargent Florence as "the use of scientific method to provide executives with an analytical and objective basis for deduction". Its main difference from the studies of social science and economics lies in the fact that it is in each case specific to the problem which it is tackling—it does not assume that any of the already existing theories connected with the particular piece of work being investigated are necessarily reliable, nor does it rely on deductions from any general body of industrial, economic or military theory. It tackles the limited problem offered for its examination by tracing the relationship of the various factors (the data of the case) to the points about which the executive had to make his decision.

Thus in studying the problem of reducing the cost of the turn-round of the ships carrying iron ore to a certain port, the problem was seen by the executive as one of reducing the time of the turn round. As seen by the operational

research worker, it became one of finding out what was the best type of equipment to instal at ports and how it should be operated so as to minimise the total cost of discharge, a cost which included both the expense of the actual unloading operation as well as the expense incurred by keeping the ship inactive in port during the unloading.

The problems which can be tackled are manifold: the rearrangement of patients' attendance hours at hospitals to give minimum wastage of both patients' and doctors' time; the development of efficient, quick-flowing information channels within a single factory, a part of an industry, or a whole industry; town and country planning surveys; and studies of accident and road traffic problems such as those which led to the 'zebra' crossings, all come within the scope of operational research.

Difficult to define because of its limited objective and its flexible mixture of scientific theory and experiment, it is always 'to the point', whatever heresies against the traditions, established practice or theories this approach may involve.

A HUMAN CHIMERA REVEALED BY BLOOD-GROUPING

In the history of human blood transfusion the blood of tens of thousands of persons has passed through blood-grouping laboratories in all parts of the world. In the course of the testing the variety of groups and sub-groups of human red blood cells has grown in profusion; to Landsteiner's original ABO blood group system have been added such further refinements as the MNS, the P, the Rh, the Lu, the K, the Le, the Fy and the Jk systems. Yet in all that time nowhere was there found a person with cells of more than one group in any particular system.

Now such a person has turned up in Sheffield, Mrs. McK. A young mother, aged 25, healthy and normal in every obvious respect, she presented herself at the Sheffield National Blood Transfusion Service to donate a pint of her blood. When the Transfusion Service personnel carried out the routine typing of her blood for its ABO blood group they were amazed to find that though some of the red cells would agglutinate with anti-A serum, many would not.

So unprecedented was this phenomenon that a sample of the woman's blood was forwarded to the Medical Research Council's Blood Group Research Unit at the Lister Institute in London. There the blood grouping was repeated—with identical results. There could be no question but that the red cells in the blood sample were of two distinct varieties. About one-third of them were of blood group A_1. The other two-thirds were of blood group O. In two of the other blood group systems the cells also differed. The A cells were Kk, Jk (a−b+); the O cells were kk, Jk (a+b+).

One obvious way to account for this dual red blood cell picture would be on the basis of a recent transfusion of O cells into an A person. But in this case there was no history of a blood transfusion at any time, recent or otherwise. The mystery was solved when Dr. R. R. Race, Director of the Blood Group Research Unit, drew on an analogous situation known to exist in cattle.

Cattle, like humans, have blood groups, but unlike the human family, cattle not infrequently possess red cells of two different groups. In such cases it has been shown that the animal involved was one of twins. Between bovine twins there is usually a fusion of the blood vessels in the embryonic membranes and often primordial red cells migrate from one twin to the other through the common network of blood vessels. Such primordial cells become implanted in the blood-forming tissues of their new host and, in later life, continue to manufacture their own group of red cells. If these cells are of a different group from that of the host's own red cells, as not infrequently happens in the case of non-identical twins, the animal carries the two types of cells side by side in its blood stream. In effect, a natural graft-hybrid has been produced.

The question went back to Sheffield: Was the young woman a twin? Indeed she was, but her twin brother had died 25 years ago at the age of three months. And the only likely explanation for his twin sister's dual blood groups was that in her still lived some of his red cell-forming tissue.

From a blood transfusion standpoint the discovery of a person with cells of two different blood groups can have little significance. The condition must be exceedingly rare. Twins only occur once in about eighty-three births, and of fifty-eight other pairs of dissimilar twins tested by the Blood Group Research Unit none showed evidence of mixed blood groups. But in other respects the finding is most important, as it brings new information on certain little-understood physiological processes.

One of these is the response of the body to foreign substances to which it may become exposed in early foetal life. Unlike the effect in the adult animal, which responds by making antibodies to the foreign antigen, a foreign substance in the foetus seems to cause an actual specific inhibition of antibody formation. This is shown in the present case by the absence of anti-A, which normally occurs in the blood serum of O group individuals. The early exposure of the young woman to the A cells she acquired from her twin brother suppressed the anti-A forming mechanism of her own O constitution, though her anti-B synthesising mechanism is left unimpaired.

"But perhaps the most fundamental finding", says an Annotation in the *British Medical Journal* (July 11, 1953) where the original article appears, "was that the genetical control of salivary secretion of the blood group substance does not operate through the red cell at any stage of the cell's existence." This refers to the fact that many people secrete their blood group substance in their saliva. The young woman in question is a secretor, but she secretes only her own O substance, despite the fact that her blood is one-third loaded with her twin brother's A cells. This shows that secretion of a blood group substance depends not on the fortuitous presence of red cells of that group, but on the true genetic inheritance of that particular blood group.

There is also a story behind the title given to their article by the scientists who collaborated in the discovery. They call it: "A Human Blood-Group Chimera". This may produce some perplexed lifting of eyebrows among those accustomed to the common dictionary definition of a chimera as a mythical she-monster having a lion's head,

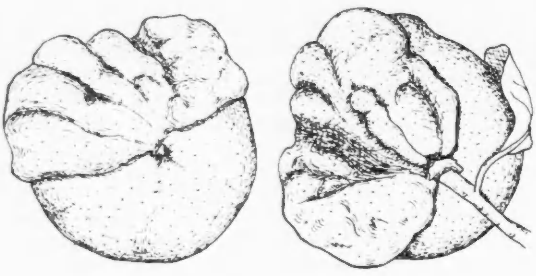

FIG. 1. The Bizzarria Orange. In these two views of a typical fruit produced by this graft hybrid it can be seen that part of the skin is smooth; the rest of the skin is furrowed, and yellow with orange streaks.

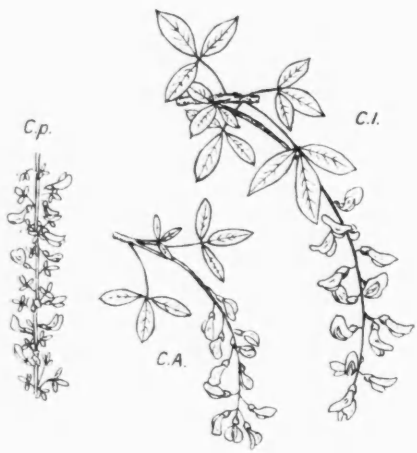

FIG. 2. The inflorescence of *Cytisus Adami* (*centre*), a graft hybrid of laburnum (*right*) and purple broom (*left*).

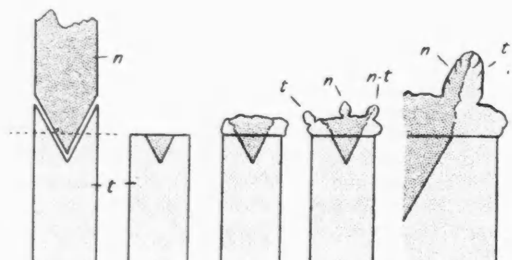

FIG. 3. Winkler's technique for creating graft hybrids. *n*, nightshade; *t*, tomato. The bud *n-t* in *D* gives rise to a chimeral branch.

goat's body and serpent's tail; apparently the title raised the eyebrows of the *B.M.J.* sub-editor who first read it! Biologists have adopted the mythologists' word and use it for an organism (plant or animal) made up of two genetically distinct tissues.

Using the word in this sense, one may say that Mrs. McK. proved in effect to be a chimera in so far as the tissue producing her blood corpuscles is made up of two genetically different types of cells.

The blood-group experts concerned in this history-making discovery are I. Dunsford, C. C. Bowley and Ann M. Hutchison of the Sheffield Unit, and Joan S. Thompson, Ruth Sanger and R. R. Race at the London end. Marie Cutbush, of the Medical Research Council Blood Transfusion Research Unit, counted the relative numbers of the two kinds of red cells.

PLANT CHIMERAS

Though very few chimeras have been noticed in the animal world, such forms with a composite genetical nature are by no means rare among plants. The term 'graft hybrid' used to be applied to these freaks, but this has now been superseded as some chimeras have arisen which involve no grafting process.

The first chimeras described in scientific literature was the Bizzarria Orange (Fig. 1). This freak was described in the Royal Society's *Transactions* of 1667 (Vol. II, p. 553) in the following words:

> *Some* Hortulan *Communications about the curious engrafting of* Oranges *and* Lemons *or* Citrons *upon one another's Trees, and of one Individual Fruit, half* Orange *and half* Lemon, *growing on such Trees, etc.*
>
> 1. We have here *Orange-tree* (*saith the Intelligence from Florence*) that bear a fruit, which is *Citron* on one side, and *Orange* on the other. They have not been brought hither out of other Countries, and they are now much propagated by Engrafting.
>
> 2. This was lately confirmed to us by a very ingenious *English* Gentleman, who asserted, that himself not only had seen, but bought of them *An.* 1660 in *Paris*, whither they had been sent by *Genoa* Merchants; and that on some Trees he had found an *Orange* on one branch, and a *Lemon* on another branch; and also (consonantly to the *Florentine* information) one and the same Fruit half *Orange* and half *Lemon*; and sometimes *three-quarters* of one kind, and *one-quarter* of the other.

According to one modern authority (W. Neilson Jones) the Bizzarria Orange is an authentic graft hybrid. Almost certainly this chimera was the product of a grafting operation in which the scion was a sour orange (*Citrus aurantium*) and the stock a citron (*C. medica*). The plants that resulted from the vegetative propagation of this graft hybrid had a core of citron and a skin of sour orange. Such plants could yield three different types of fruit—firstly there were the fruits characteristic of citron and of sour orange, and then the third type of fruit comprising a mixture of genetically different tissues, so that part of it resembles the scion's fruit and the rest of it the stock's fruit.

Probably the most striking of all such graft hybrids is the plant called *Cytisus Adami*. This dates back to 1825 when a French nurseryman called Adam budded a scion of *C. purpureus*, the small purple-flowered broom on a stock of laburnum, his intention being to obtain a 'standard' of the former. The bud appeared to perish, but alongside it arose a small adventitious bud which developed into a

shoot. From this shoot by cuttings many specimens of the graft hybrid named *C. Adami* have been propagated. The leaves of this plant resemble those of laburnum, though they lack the characteristic hairs on the lower surface. The inflorescence has one or two characteristics of the laburnum, but the colour of the flowers is more like that of the purple broom—they are purple-brown in colour. In general the flowers set no seed. All attempts to cross the two species have failed, so this particular chimera is evidently a perfect graft hybrid.

The beginning of modern research on these freaks of nature dates back to 1907 when Hans Winkler set out to produce graft hybrids. He grafted black nightshade (*Solanum nigrum*) on tomato. After the graft had taken, a cut was made across the stem (Fig. 3A). From the exposed surface buds grew, and these grew into new shoots. Nearly all of these shoots were typical nightshade or typical tomato shoots. But he did find that when a bud arose at the junction of the two genetically different tissues (Fig. 3D and E) the shoot resulting had the characteristics of nightshade on the one side and tomato on the other.

Some chimeras arise because a genetic mutation has occurred in some cell or cells of the growing point of a shoot. This type of spontaneous chimera is quite common, and keen gardeners among our readers are bound to be familiar with some of the variegated chimeras (e.g. the mosaic *Pelargonium*) which have originated in this kind of way.

The most easily accessible book on this subject is W. Neilson Jones's *Plant Chimeras and Graft Hybrids*, a Methuen biological monograph published in 1934.

AGRICULTURAL RESEARCH

Judged by any standard of quality and effectiveness, the British research effort in the agricultural field looks impressive. Moreover, the network of agricultural research units that now exist is large and comprehensive in its coverage; in fact that network has practically reached the stage when it can give useful attention to any new problem that arises.

Oldest of our agricultural research stations is Rothamsted. This was started in 1843 by John Bennet Lawes and financed out of the profits of his superphosphate business —a reminder that artificial fertilisers were the first of the scientific aids to revolutionise farming practice. Following the lead of Boussingault in France, Lawes and Henry Gilbert began experiments on the fertiliser requirements of crops, and from that nucleus of research grew the whole wide panoply of Rothamsted research.

Today a considerable amount of agricultural research is financed not by private individuals or by commercial firms but by the community. It is a matter of historical fact that State aid for agricultural research was slow to come. It was not indeed until the early years of the 20th century that the British Government began to take any really keen interest in scientific agriculture and started to devise the steps required to encourage research in this direction. The stimulus which led to this action was provided by that most powerful of forces—acute economic necessity. British agriculture was in a state of serious depression, and this fact resulted in the passing of the Development Act of 1909. Under this Act a Development Fund of about £3 million was established for the rehabilitation of British farming. One of the Development Commissioners appointed to administer that fund was appropriately the director of Rothamsted, Sir Daniel Hall, who saw to it that a substantial portion of the money available was channelled into agricultural research. State aid for agricultural research has increased enormously since that time.

Today the British Government spends about £3 million a year on agricultural research, though this seems a trifling sum in these days when it is possible to spend twice that amount on an experimental aircraft like the Brabazon. There are now over 30 research institutes and research units financed wholly or partially by the State, and these are supervised by the Agricultural Research Council, which is agriculture's counterpart of the D.S.I.R. and the Medical Research. The reader who wants a concise account of the organisation of this large nexus of research units cannot do better than consult the booklet which the A.R.C. has produced under the title *The Agricultural Research Service* (H.M.S.O., 2*s.* 6*d.*), though the greater part of the document is in effect a directory of the thirty-odd research units. (Those readers who are interested in the career prospect offered by this service should try to obtain a copy of the A.R.C. pamphlet which is being circulated by the A.R.C. from their headquarters in Cunard Building, 15 Regent St., London, S.W.1.)

As the first of these two documents points out, commercially controlled agricultural research is a powerful supplement to the public service. Nowadays industry is doing a considerable amount of research in this field. Here again one is reminded of Rothamsted and Lawes, and of the fact that it was the application of artificial fertilisers which led chemical firms to follow in Lawes's footsteps, both on the production side and on the research side. One of the most important agricultural stations maintained by an industrial firm is Jealotts Hill in Berkshire, which belongs to Imperial Chemicals. This station has just been celebrating its 25th anniversary.

Jealotts Hill was a 500-acre farm when it was bought by I.C.I. in 1927, and when it opened as a research station in 1928 it had a research staff of about a dozen. Today that figure has increased to about 120.

In the first years the work at Jealotts Hill was mainly concerned with the study of chemical fertilisers and the part they could play in increasing agricultural production.

From the earliest days it was realised that chemicals could also play an important part by helping the farmer to control the pests, fungi and weeds which harmed or strangled his crops. Indeed it is in these fields that two of the most famous and important successes of the station have been achieved. In 1941–2 MCPA ('Methoxone'), the first of the so-called hormone weedkillers, was discovered by Dr. W. G. Templeman at Jealotts Hill.* This selective weedkiller kills charlock and other weeds in cereals, linseed and grass, while leaving the crop unharmed.

* Reference to the classic issue of *Nature* (April 28, 1945) containing the delayed report of this discovery shows that experiments carried out in November 1941 established that MCPA was one of the most active compounds out of a list of thirty-two plant hormones tested for weedkilling activity.

Testing the chemical contest of soil drainage water at Jealotts Hill.

In 1943, a second major discovery was made in I.C.I.'s plant protection laboratories at Hawthorndale, a neighbouring country house which had been converted into laboratories for the study of pesticides and insecticides nine years previously. This new substance, the gamma isomer of benzene hexachloride (now well known as 'Gammexane') has proved to be one of the most useful insecticides known. It has, as the Minister of Agriculture, Sir Thomas Dugdale, pointed out at the Silver Jubilee anniversary celebrations at Jealotts Hill on July 15, done much to solve the age-old problem of the wireworm. It has also proved effective against locusts, mosquitoes and many other insects of major economic importance.

Tests for new chemicals of potential agricultural interest are in progress continuously both at Jealotts Hill (which is responsible for weedkillers and plant-growth regulators) and at Hawthorndale (responsible for pesticides and fungicides). The chemicals are sent to the station from the Chemical Research Laboratories of I.C.I. and because it is impossible at present to predict the biological effects of a chemical from its formula and structure, they are submitted to a series of routine tests. In examining chemicals for insecticidal properties for example, a regular battery of tests is applied. A sample of the chemical at a concentration of 200 times that necessary if Gammexane were used, is tried out first on the larvae of the yellow fever mosquito, *Aedes aegypti*. It is then sprayed on to a broad bean plant which is also watered with a solution of the chemical, and subsequently infested with pea aphides (*Macrosiphum pisi*). Finally it is tried out against the red spider (*Tetranychus telarus*). Any marked success in these tests leads to further experiments and these are coupled with studies of their possible toxicity to humans and farm animals. Similar tests are undertaken with regard to potential fungicidal action. It is interesting to note that at the moment special effort is being made in the hope of finding a reliable systematic fungicide. An average of 1200 different chemicals are tested in this way at Hawthorndale each year, though few are found worthy of being carried forward for further development.

Side by side with these newer branches of investigation, the work in the older fields of fertilisers and the effects of soil chemistry on crop growth has also continued and expanded beyond recognition.

An interesting and important success resulted from an intensive study of the Teart pastures of Somerset. These fields, which are often isolated from one another and situated in the midst of good, unaffected pasture land, are estimated to occupy about 20,000 acres of Somerset farmland. Cattle feeding on them either scour and become badly sick, or become bloated. All earlier attempts to discover the cause of these troubles had failed, but as the result of an intensive study which was commenced in 1937, three scientists from Jealotts Hill (W. S. Ferguson, A. H. Lewis and S. T. Watson) discovered both its cause—the occurrence of traces of molybdenum in the soil—and a number of methods for alleviating the condition.

The research policy of Jealotts Hill is an enlightened one, and investigations are made along many lines which do not offer any immediate prospects of giving results that can be applied. For instance, on our visit to the station we saw experiments in progress into the possibilities of using the alga *Chlorella* as a source of food, which is an idea that cannot possibly find useful application in less than a decade.

Much of the work at Jealotts Hill is concentrated on the improvement of the 14 million acres of grassland which occupies the major portion of our farming land. Studies in the use of nitro-chalk fertilisers have led to striking increases in yields of grassland, and on the basis of the results so far obtained, it is estimated that by the proper manuring of only 6 million acres of grassland out of the 14 million available (thus leaving ample pastureland for grazing), the production of high-protein-content dried grass could be increased by 6 million tons, a figure which is equivalent to 1 million additional tons of protein for feeding stock.

Certainly our grassland could be much improved, and it is here that the increase in agricultural production (an increase of over 50% over pre-war production) could most easily be carried rapidly forward. Yet if the studies now in progress at Jealotts Hill and at many other research stations throughout Britain have any wide application, it may well become true that, as Mr. S. W. Cheveley suggested, "this century will be written in history as the grassland age".

THE SIGNIFICANCE OF BACTERIAL POLYSACCHARIDES

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Viscous slimes and mucilages have been known to be closely associated with the life cycle of bacteria since the time of Pasteur who was probably the first man to recognise that the slimes were actually the products of microbial attack on the simple sugars. The first polysaccharide to receive close analysis was that separated from the gum-like mass of ropy sugar in refineries. It was the dextran of Scheibler (1874), who described it as the product of the fermentation of sugar by a coccus, *Leuconostoc mesenteroides*. Lippmann (1904) showed that the gum had the elementary composition $C_6H_{10}O_5$, that it had a highly positive or 'dextro' optical activity when dissolved in water and examined in the instrument known as a polarimeter. He showed that the gum contained units of glucose.

Evidence gradually accumulated to show that polysaccharides could readily be formed by the action of both pathogenic and non-pathogenic micro-organisms, and that they had properties which related them to the gums and mucilages synthesised by plants.

It is now well established that all microbial cells have the capacity to synthesise polysaccharides at some stage at least in their life cycle. The complex sugar may be formed as an extra-cellular mucilaginous layer of unusual thickness, which serves as a defensive mechanism and protects the cell in whatever surroundings it may find itself. Thus the chemically stable surface polysaccharides of soil bacteria such as the species of *Rhizobium* (found in the root nodules of peas, beans and other leguminous plants) probably protect the cell against destruction by soil protozoa and fungi; the attack of pneumococci on the human body is always more virulent when these bacteria are surrounded by the polysaccharide 'capsule' which protects them against the body's phagocytes.

Some polysaccharides assist in forming structural and skeletal material of microbial cells; for example, in the case of the tubercle bacillus they appear to be firmly combined with complex fatty acids near the bacterial surface. In such combination the microbial polysaccharides are completely water-insoluble.

The wefts (mycelia) of most moulds have a high content of polysaccharides, which play a role similar to that of cellulose in plants.

In most bacterial cells certain polysaccharides act as food reserves similar to the starches of plants and glycogens of the animal body. It has been found in recent years that glycogens and starches are readily synthesised by many micro-organisms, including protozoa, and that the enzymes which make the starch-type polysaccharides from glucose-1-phosphate have strikingly similar properties no matter what their origin. Protozoa can use acetic acid as a source of carbon from which to form starch.

Many of the energy-reserve polysaccharides are undoubtedly built up in the earliest stages of cell division and they can be demonstrated as soon as the cells start dividing.

The cell can readily ring the changes on the kind of energy-reserve polysaccharide it synthesises. Thus one has seen with cultures of the particular species of *Penicillium* (shown in Fig. 1) that after twenty-four hours the fungus synthesised significant quantities of a relatively unstable polygalactose; after three days the sole polysaccharide in the medium was a stable polymannose, whereas after ten days a highly stable polyglucose was the only polysaccharide present. These metabolic stages have not yet received much attention from microbiologists or chemists, but they provide a fascinating field for future study.

POLYSACCHARIDES AND PNEUMONIA

The most significant property which has been ascribed to the bacterial polysaccharides is their ability to stimulate in a remarkably specific way the defence mechanisms of the animal body during attack by pathogenic micro-organisms. This type of study was initiated by Avery, Heidelberger and their colleagues in the Rockefeller Institute, New York, some thirty years ago. While examining patients suffering from lobar pneumonia, they found that the patients' blood and urine contained substances closely similar to certain soluble substances which had previously been isolated from the pneumococcal cells themselves, i.e. from the bacteria which caused the disease. They learned how to cultivate the pneumococcal cells in test tubes and

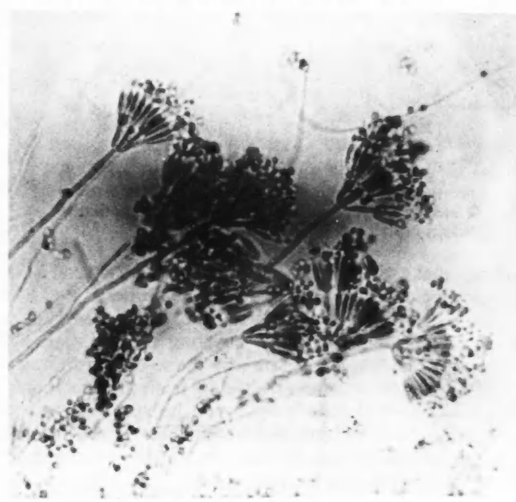
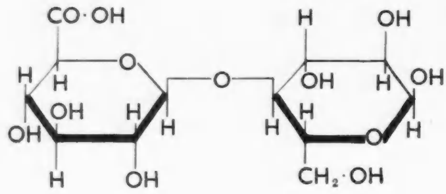


FIG. 1. The mycelium of a species of *Penicillium* (*P. luteum*) which produces various polysaccharides during its life cycle.



GLUCURONIC ACID——GLUCOSE

FIG. 2. α-Cellobiuronic acid. In this compound, wherever it may occur, the acidic (–CO·OH) groups always appear to be free to take part in salt- or ester-formation.

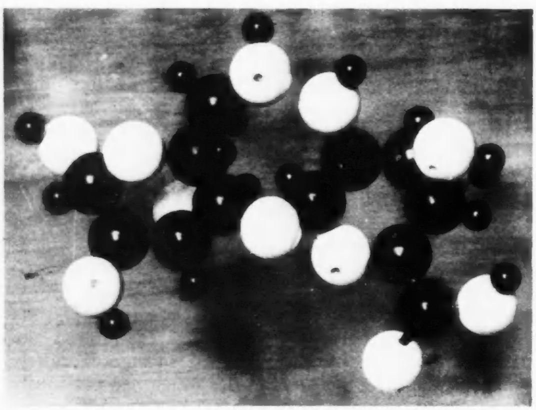


FIG. 3. Haworth-type model of cellobiuronic acid.

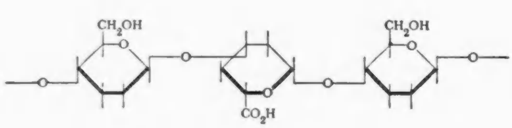


FIG. 4. The Type III pneumococcus polysaccharide forms highly viscous solutions in water. It possesses a molecule of cylindrical shape and has a molecular weight of half a million.

how to make the soluble substances, which were of a polysaccharide nature, in quite large quantities.

Minute traces of the polysaccharides, which were shown to originate from the capsule covering the cell, had the property of giving a precipitate with the so-called 'immune' serum of patients or animals suffering from the pneumonia disease. The precipitate was formed because the soluble immune proteins (the 'antibodies') in the serum, reacted with the soluble polysaccharide (the 'antigen') to form an insoluble macromolecule which rapidly fell out of solution. The antigen-antibody (or 'precipitin' reaction as it is called) which can be demonstrated so well in the test tube had been studied with protein antigens only. The reactions were known to be sharply specific, and the specific properties depended to a large extent upon the chemical nature of certain components of the protein molecule. It had become valuable to use specific precipitin reactions for the detection of minute amounts of proteins and for the diagnosis of certain infectious diseases.

It now became possible to study the reactions which occur when bacterial polysaccharides were used as the specific antigens. Since some of the polysaccharides were free of nitrogen a measure of the 'protein-nitrogen' content of the specific precipitate gave an estimate of the immune protein in it.

Bacteriologists found from their studies on pneumonia that the disease was caused by various different types of pneumococcus, e.g. Types I, II, III, V, VIII, etc. It was shown later by the chemists that each type was possessed of a chemically different polysaccharide which was located in the bacterial capsule. The precipitin reaction was sharply specific for each polysaccharide. Thus strong precipitation occurred when a solution of the polysaccharide, containing one part dissolved in one million parts of water, was added to a diluted solution of the corresponding homologous antiserum. Thus:

Type II pneumococcus specific polysaccharide (1 part per million)	+	Type II antiserum (diluted 10 times)	→	Strong 'precipitin' reaction

When the Type II polysaccharide was added similarly to antiserum from Type IV, for example, there was little or no reaction.

On the other hand significant reactions did occur when strong concentrations of other Type-specific polysaccharides were used; for example, Type III polysaccharide reacted with the same Type II antiserum thus:

Type III polysaccharide (1 part in 10,000)	+	Type II antiserum (diluted 10 times)	→	Strong 'precipitin' reaction

These 'cross precipitin' reactions as they are called have been of great value in relating chemical constitution to serological specificity. In the pneumococcus group it has been shown that a certain oxidised sugar derivative, having the properties of an acidic disaccharide, possesses most powerful determinant properties. This substance has the structure as shown in Fig. 2, which is that of cellobiuronic acid in which the $-CH_2OH$ group of the sugar molecule has become oxidised. In this molecule glucuronic acid, which forms an important normal constituent of the animal body, is combined with glucose; Fig. 3 shows a molecular model of cellobiuronic acid.

This acid occurs most abundantly in the polysaccharide (Fig. 4) of the Type III pneumococcus. It is also found in the Type II and Type VIII pneumococcus polysaccharides, in Friedländer's bacillus, in polysaccharides characteristic of *Rhizobium* and *Azotobacter*, and in artificially prepared oxidised cellulose, all of which give strong cross-serological reactions with the Type III antiserum. Closely related acidic disaccharides occur in some plant gums, such as gum arabic, and they, too, give cross reactions with various pneumococcus antisera. When cellobiuronic acid is combined chemically with a protein and injected into animals

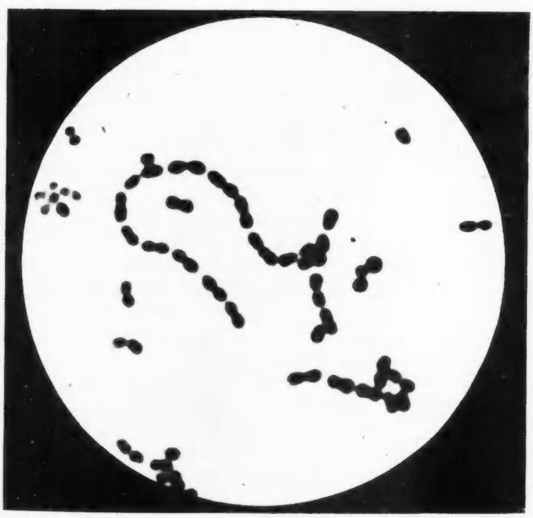
the synthetic vaccine gives rise to antibodies which will protect mice against various types of pneumococcal infection.

The pneumococcal polysaccharides when used in very small doses as vaccines will immunise human beings against infection by the homologous type of pneumococcal infection, and a valuable weapon is thus available which can be used as a supplement to drugs and antibiotics in pneumonia treatment.

Other pneumococcus polysaccharides possess as building units certain nitrogen-containing sugars one of which is related to glucose and termed glucosamine. Glucosamine and its derivatives are being intensively studied at the present time since they have been shown to occur in a wide variety of biological tissues. Glucosamine forms the major organic component of the chitin of crab and lobster shells, and of insects' wings where it occurs in combination with acetic acid and proteins. It occurs in blood cells, in joint fluids, in bone, cartilage and tendons, in the fluids and tissues of the eye and nose, etc. It is found also in mushrooms and the lower fungi, but so far it has not been found in higher plants. It is said to exert an influence on the growth of certain tumours and it is a constituent of streptomycin. Its function as a determinant group in serological reactions is not yet understood.

In many tissue polysaccharides, amino sugars are combined in a remarkable way with glucuronic acid. Thus a polymer of a glucosamine-glucuronic acid disaccharide termed 'hyaluronic acid' is found in hyaline tissue, in nasal fluid, in the ground substance of many tissues, in the human umbilical cord, etc. By a remarkable achievement of nature some bacteria are able to synthesise hyaluronic acid apparently identical with that from animal tissues. The bacteria are certain haemolytic streptococci which are pathogenic and may cause rheumatic fever. A good deal of effort is being made at the present time to understand the role in rheumatic conditions of both animal and bacterial hyaluronic acid, and of the enzymes which control its molecular size.

In the streptococcal group of micro-organisms there are many which cause diseases such as blood poisoning. A study of the polysaccharides they produce has been of great value in the classification of the species. Prior to 1920 studies on the streptococci were limited to morphological and cultural characteristics and classification was difficult. Studies by Dr. Rebecca Lancefield in the U.S.A. on antigenic constituents and the isolation by her of so-called 'species specific' and 'type specific' substances, some of which are proteins and some polysaccharides, has provided an important new method of classifying streptococci. The chemical structures of the polysaccharides have not been determined except in a few cases where they have been shown to be 'levans' which are polymers of fructose. Streptococcal infections are now kept under control by the use of sulpha drugs and by antibiotics such as penicillin. Polysaccharide-splitting enzymes from leech extracts have been studied for this purpose. Minute doses of penicillin (in amounts insufficient to kill the cells) exert a profound influence on the morphology of the cells. The normal processes of cell division are upset and surface components are altered. An example of these is shown in Figs. 5 and 6. It is almost as though the parasite itself had contracted a disease! When in this state, certain streptococci lose their power to produce surface polysaccharides. Similar effects



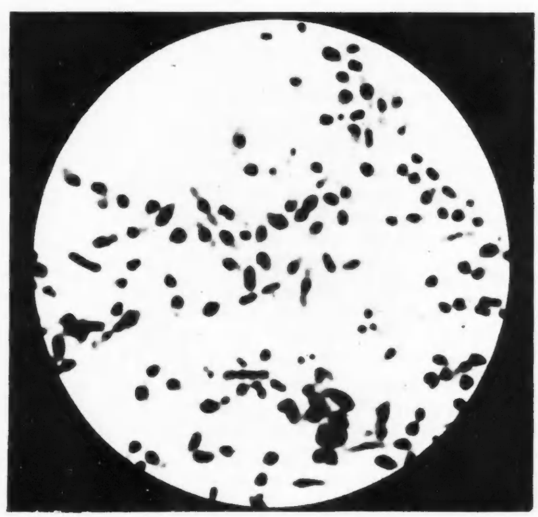


FIG. 5 (*left*). The normal chain-like form of a *Streptococcus*. It stains strongly positive with Gram's stain and produces large quantities of the polysaccharide called levan from sucrose.

FIG. 6 (*right*). The same strain of *Streptococcus* as shown in Fig. 5, but growing in presence of a trace of penicillin (dilution of 1 in 500,000). The normal chain form is lost, the staining by Gram's stain is erratic and the ability to synthesise polysaccharide is largely lost.

are obtained when the organisms are starved of magnesium, and also when they are attacked by bacteriophages. In this state they are often less virulent.

The drug Gramicidin was developed as a result of studies on the enzymic breakdown of bacterial polysaccharides.

The *Leuconostoc* organisms which produce dextrans belong to the *Streptococcus* species. These particular polysaccharides are now used to provide material suitable for use as blood plasma substitutes or blood volume expanders. This use is due to their colloidal nature, for after a certain amount of 'tailoring' of the macromolecule, their solutions in physiological saline possess viscosity and general colloid properties closely similar to those of the plasma proteins.

They are relatively unaffected by enzymes, they can be prepared economically on a large scale, they can be stored indefinitely even in hot climates and they do not carry the jaundice virus which is sometimes a trouble with natural blood plasma. More important still they are completely metabolised in the body, for the tendency to become stored in the liver and in the skin is a drawback of some of the purely synthetic colloids. Dextrans are the first polysaccharides to be made on a large scale by a fermentation process. The polysaccharide-synthesising power can be stimulated enormously, and one has seen a 10% solution of cane sugar (sucrose) converted into a mass of dextran jelly within a few hours.

The synthesis takes place by the agency of extra-cellular enzyme systems which in most organisms need sucrose specifically as material with which to build the big molecules. Sucrose is composed of glucose and fructose units. The enzyme builds up the large molecule from glucose only and rejects the fructose.

A remarkable amount of knowledge is now available on the enzymes which synthesise polysaccharide molecules. Thus for the synthesis of plant, animal and microbial starch components two distinct enzymes are needed. One is the 'P' enzyme which links up glucose units to form a long straight-chain molecule termed 'amylose' which coils to form a spiral, stains deep blue with iodine, and has many of the physical properties of cellulose. The second is the 'Q' enzyme which divides the amylose into small portions and then binds these together to give a highly branched molecule which has many of the properties of pectin jelly and which stains red with iodine.

Dextrans (Fig. 7) in a similar way are constructed by two enzymes, the first of which builds up a straight-chain molecule and a second one which causes branching. (Further particulars about this will be found in the research paper which is the third item given in the Reading List at the end of this article.)

Some micro-organisms contain enzyme systems which can change the linkage of one kind of polysaccharide into that of another. Thus *Acetobacter capsulatum* will act upon starch dextrins and convert them into dextrans effecting what the carbohydrate chemists call the switching of a 1:4 glucosidic linkage into a 1 : 6 glucosidic linkage. Very small energy changes are involved in these transformations. Economically they are important since 'ropy beer' and 'ropy cider' are in the writer's opinion caused by contaminating 'wild' organisms effecting 'switchovers' of this type.

When dextrans are broken down into the relatively small molecules (e.g. those of molecular weight 60–80,000) used in blood volume expanders, they lose their serological properties almost completely. In general with bacterial polysaccharides the serological properties are most pronounced and most specific when they are in the highest molecular state, i.e. having molecular weights of the order of millions. The specific serological properties of the polysaccharides have been of enormous value in the study and treatment of many infectious diseases. They are largely used in the diagnosis of diseases such as cholera, anthrax, meningitis, typhoid fever, dysentery, etc.

Apart from the diagnostic value it is well established that many effective vaccines which are widely used in the prophylaxis or prevention of disease, e.g. as in anti-typhoid and -paratyphoid, anti-cholera, anti-whooping cough vaccines, etc., contain a high proportion of polysaccharide material. These have been particularly studied in those organisms which cause food poisoning, typhoid fever and dysentery. The polysaccharides, which occur in the form of complexes with fatty acids and with a phosphorus-containing substance, possess amino sugars, galactose and sometimes rhamnose as constituent units. Knowledge of their chemical structure is not yet available.

Cholera is a disease which like anthrax has been known from ancient times. It is caused by micro-organisms known as 'vibrios', comma-shaped bacteria of which the tail of the comma acts as a motile organ enabling them to spread rapidly in a liquid medium. The disease is kept under control by strict public health measures and by vaccination,

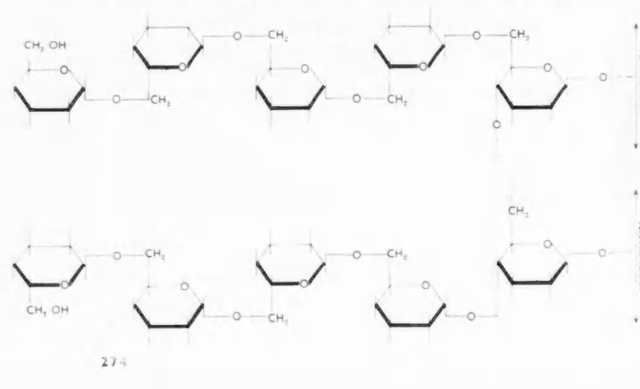


FIG. 7. The dextran from *Betacoccus arabinosaceus*. Dextrans are characterised by having chains of glucose units linked mutually through the 1 and 6 positions. In some dextrans linkages occur between other positions and give rise to molecules in which the chains are highly branched.

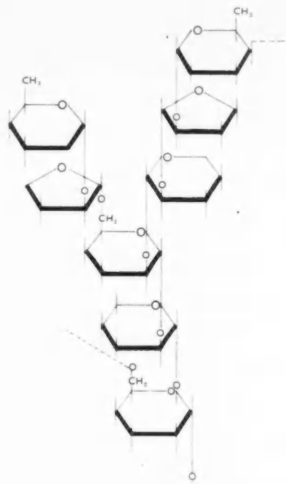


FIG. 8. 'Skeleton-type' formula of the repeating unit of one of the polysaccharides from *M. tuberculosis*. The unit is built up from glucosamine, mannose, arabinose and rhamnose.

but it is still a dreaded menace in the East. Further knowledge of the immunology of the disease, especially of the nature and function of the various specific polysaccharides which are known to be produced abundantly by the vibrios, will be needed before the disease can be eradicated.

Polysaccharides are of great importance in the study of tuberculosis. The causative agent is termed *Mycobacterium tuberculosis* and it is remarkable for the ease with which it can be cultivated in artificial medium. It is produced on a large scale in a liquid containing glucose, mixed amino-acids, mineral salts and glycerol, in order to produce special proteins used most successfully by the Ministry of Agriculture Veterinary surgeons in the 'T.T.' testing of cattle. The cell appears to possess an unusual life cycle, which is not yet properly understood, and it contains a high proportion of fats and waxes in its make-up and these appear in firm combination with some of the complex polysaccharides of the cell.

The polysaccharides (Fig. 8) are numerous—five or six distinct types being known. Their serological properties show a surprising lack of specificity while their chemical nature is extraordinarily diverse and complex. Two of them possess units of mannose, glucosamine and arabinose.

The arabinose—a pentose type of sugar—was found to occur in the unusual 'D' series and in the 'furanose' or five atom ring form—this being the only time this sugar has been found in nature in this form. Parts of the structure of two of the *M. tuberculosis* polysaccharides bear a superficial resemblance to the antibiotic streptomycin which itself is a complex saccharide made by microbial action. It is perhaps significant that streptomycin is becoming established as one of our remedies against the disease. It may act in some measure by preventing the polysaccharide formation which is an essential part of the growth process of the bacillus.

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A COMMONWEALTH BURSARIES SCHEME

The Royal Society and the Nuffield Foundation announce their joint decision to initiate a Commonwealth Bursaries scheme. The Nuffield Foundation is supporting this bursary scheme as a complement to its established programme of Commonwealth fellowships and other awards.

Put concisely, the objective of the scheme is to provide facilities for increasing the efficiency of investigators of proven worth by enabling them to pursue research, learn techniques or follow other forms of study where either or both the physical and personal environment overseas in the Commonwealth is peculiarly favourable. The main difference from the ordinary research fellowship is not merely one of duration but of emphasis as the bursaries will aim not so much at obtaining the answer to a particular question as at improving the powers of the recipient to extend the bounds of knowledge.

The scheme will be operated for an experimental period of five years during which time the Nuffield Foundation will provide £5000 a year and this will be devoted to bursaries to United Kingdom scientists who wish to go to oversea parts of the Commonwealth and to scientists of one oversea part of the Commonwealth to go to another. Initially the Royal Society will also make a contribution of £2500. It is hoped that funds may be obtained from other sources to make possible the full development of the scheme.

Each bursary will provide for the cost of travel and maintenance normally for periods of two to twelve months. The applicant must be sponsored by a recognised research authority and must produce evidence that he or she has prior permission to work in the laboratory or other scientific institution chosen.

Application forms containing further details will be obtainable from the Assistant Secretary, The Royal Society, Burlington House, Piccadilly, London, W.1, and must be submitted not later than 15 March and 15 September in each year.

THE AGE OF STONEHENGE

AN EXERCISE IN RADIO-CARBON DATING

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Stonehenge is the most striking and widely known British prehistoric monument and seizes the imagination of even the most casual observer.

It may be recalled that the monument consisted essentially of a horseshoe setting of five sarsen quartzite 'trilithons' (standing stones with lintels) opening to the north-east, and lying within a closed circle of standing sarsen stones connected by lintel-stones. All these are dressed and skilfully jointed. Inside the lintelled sarsen circle and surrounding the trilithons was a presumably complete circle of 'blue stones', foreign to the site and apparently coming from the Presely Mountains in Pembrokeshire. Within the trilithon horseshoe was a smaller horseshoe of standing blue stones. The whole was surrounded by a bank and causewayed ditch and is obviously associated with a half-mile long avenue, bounded by ditches, extending in a straight line to the north-east.

Excavation has revealed three other approximately concentric circles of holes. The outermost of these is the circle of 'Aubrey Holes', just within the bank. From the recent excavation of two of these has come the material from which the radio-carbon date of the site has been determined.

PREVIOUS DATING ATTEMPTS

The consensus of archaeological opinion dates the building of the monument to the end of our Neolithic period and the beginning of the Bronze Age, perhaps about 1800 B.C.

It is well known that some Neolithic peoples were in the habit of erecting megalithic monuments. The dressed stones of Stonehenge, and the fact that it is the sole example of such masonry known to us, suggest that its building should be a late development of the megalithic tradition and that, with the Bronze-Age invasions, the tradition came to an end. There is positive evidence, in the finding of fragments of blue stone from Stonehenge in at least one long barrow (Neolithic) and in several round barrows (Early Bronze Age) in Wessex, that the blue-stone circle at Stonehenge was completed before the construction of these particular burial-mounds.

Negative evidence is almost overwhelming, in that no single object, tool, ornament or weapon of bronze has emerged from any excavation on the site. If large numbers of builders, using bronze, had frequented the place for the long period necessary for the erection of such a grandiose work, it is inconceivable that nothing of metal should have been lost or deposited there.

An astronomical date has been based on the reasonable assumption that Stonehenge was connected with some ritual observation of sunrise at the summer solstice. It is notable that, today, this event does not take place in the line of the geometrical axis of the monument and its avenue, but about 1° 12′ from it. From the known change in obliquity of the ecliptic (angle between the Earth's axis and the plane of its orbit) it was computed by Sir Norman Lockyer in 1901 that midsummer sunrise would last have taken place in the exact line of the Stonehenge axis in about 1840 B.C. (The margin of error for this astronomical calculation would be of the order of $\pm$ 200 years.) This date agrees well with the probably far less accurate result from the archaeological evidence alone.

Radio-carbon is produced in the Earth's upper atmosphere by collisions between neutrons and nitrogen atoms, and this radioactive isotope of carbon has the atomic weight (14) of a nitrogen atom instead of that (12) of ordinary inactive carbon. In due course, every atom of C^{14} reverts to inactive nitrogen by emission of an electron, in such a way that, of any quantity of C^{14}, half will have so reverted in about 5600 years, half of the remainder in a further 5600 years, and so on. This period is called the 'half-life' of radio-carbon.

Assuming the rate of its generation and the rate of its decay to be constant, the concentration of C^{14} in the Earth's atmosphere will long since have reached an equilibrium. Since it is there present as carbon dioxide gas, which is absorbed by plants, one may reasonably assume that all plants, and hence all animals which feed on the plants and on each other, contain the equilibrium concentration of C^{14} *just as long as they are alive and in direct carbon-exchange with the environment.*

As soon as a plant or an animal dies, however, it ceases to acquire fresh C^{14}, while that which it already contains breaks down at a steady rate. If, therefore, we measure the C^{14} content of some piece of organic matter which has

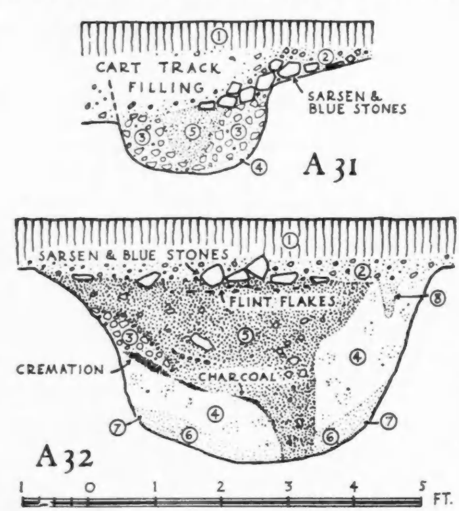
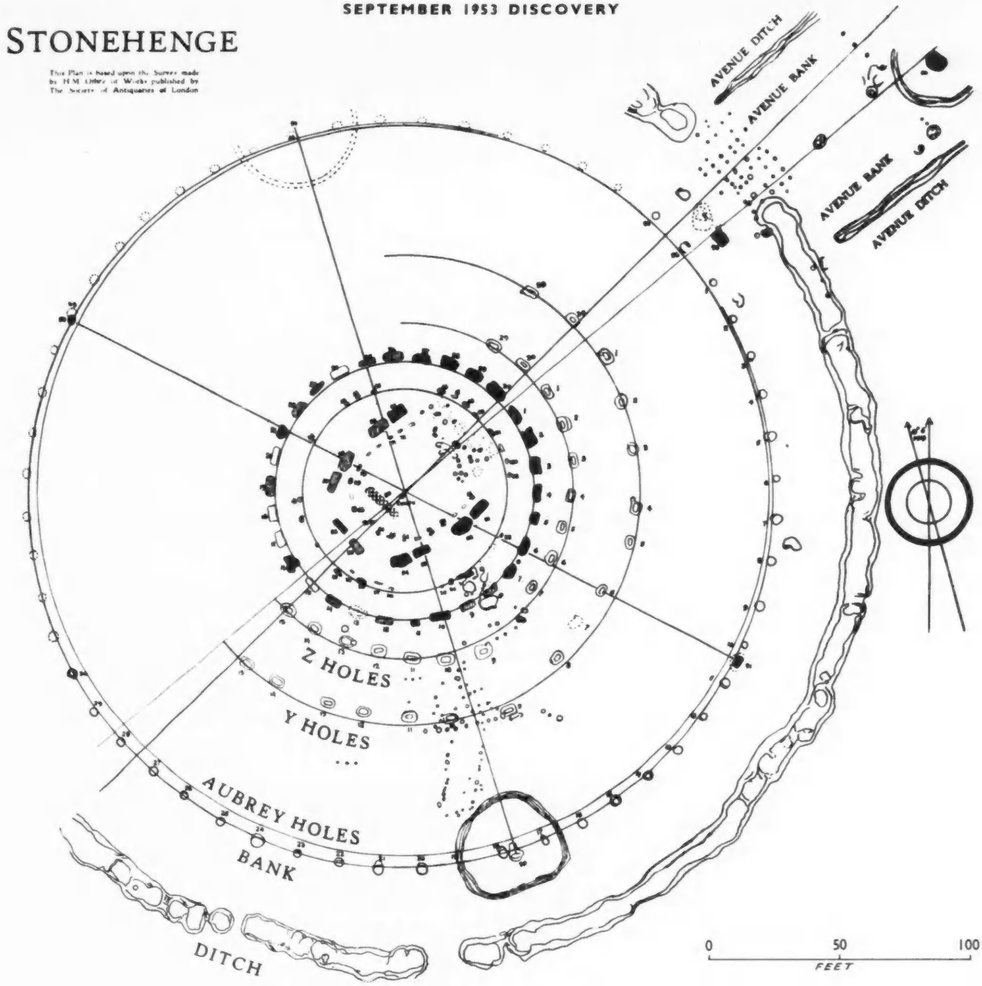


FIG. 1. Sections of the two Aubrey Holes excavated in 1950. (*Reproduced from "Antiquaries Journal", 1952.*)



Micaceous Sandstone · Sarsen, Standing · Sarsen, Fallen · Sarsen, Absent · Sarsen, Hole for · Spotted Dolerite, Standing · Spotted Dolerite, Fallen · Spotted Dolerite, Absent · Rhyolite, Standing · Volcanic Ash stump below turf · Hole for Blue Stones · Hole and Incline combined · Grave between two post holes · Z and Y holes · Post holes period uncertain · Post holes, Aubrey Circle period

FIG. 2. General plan of Stonehenge. (*Reproduced from "Antiquity".*)

been preserved in some way from long ago, we can hope to estimate its age directly by the extent to which its initial C^{14} has decayed since death took place.

When using the radio-carbon dating method in practice, pure elementary carbon or a simple carbon compound is prepared from the sample of ancient organic material such as wood, peat, charcoal or carbonised bone. The product (which may be a solid or a gas) is examined by means of a Geiger counter; the electrons released during a standard period by the decomposition of the radioactive fraction are counted, and it then becomes possible to calculate the concentration of the C^{14} present.

Quite apart from experimental errors, the method is based on several assumptions (recently discussed by Prof. F. E. Zeuner in *Science Progress*), which we are not yet in a position to prove correct. Two of the most critical assumptions are: (1) that C^{14} is uniformly distributed through all living matter; (2) that a given sample of organic matter has not been contaminated by younger carbon compounds since it was first laid down in an archaeological deposit.

As to (1), further work must be undertaken to show whether there is significant variation in C^{14} concentration in different modern organic materials. If so, it may be necessary to confine comparison of ancient samples to modern material *of a similar nature*, e.g. oak wood of antiquity with modern oak timber.

Assumption (2) is perhaps the most precarious in many

cases. Wood from a dry Egyptian tomb is possibly above suspicion, but a piece of charcoal from a prehistoric pit on an open site under the British climate may well be contaminated by percolation of humic solutions seeping out of the overlying modern soil with its cover of vegetation. Such contamination will cause the estimated age to be too small.

Practical limits are set to the age of material in which C^{14} may be estimated by the very small initial concentration and the fact that, after the lapse of (say) four half-lives, this has been reduced to a sixteenth of that originally present. For dates between 5000 and 20,000 years ago the method promises to provide a useful tool.

The radio-carbon method has nevertheless already yielded a number of dates which correspond reasonably well with those arrived at in particular cases by other methods. The radio-carbon date for an early structural phase of Stonehenge is one of these.

In 1950, two holes (Nos. 31 and 32) of the Aubrey Circle at Stonehenge were excavated (see Fig. 1) to find out whether they had ever contained either standing stones or wooden posts; but nothing to suggest either of these possibilities was discovered.

Both the primary and secondary fillings of No. 32 contained fragments of cremated human remains, and associated with the better-preserved secondary cremation was a mass of wood-charcoal, presumably the remains of the fuel used in burning the body. This yielded the material for ascertaining the radio-carbon date of the hole-filling. Aubrey Hole No. 32 was shown to represent a relatively early stage in the history of the monument.

The charcoal was submitted to Prof. W. F. Libby, of the Institute for Nuclear Studies, Chicago University. He reported an age for the material of 3798 ± 275 years before the present, i.e. a date 1848 ± 275 years B.C.

There is an encouraging, though probably deceptive, coincidence between this mean figure and the mean (1840 B.C. $\pm$ 200 years) arrived at via the astronomical method by Sir Norman Lockyer. The possible maximum difference between the extreme limits of the two estimates is a not unimportant matter of seven centuries!

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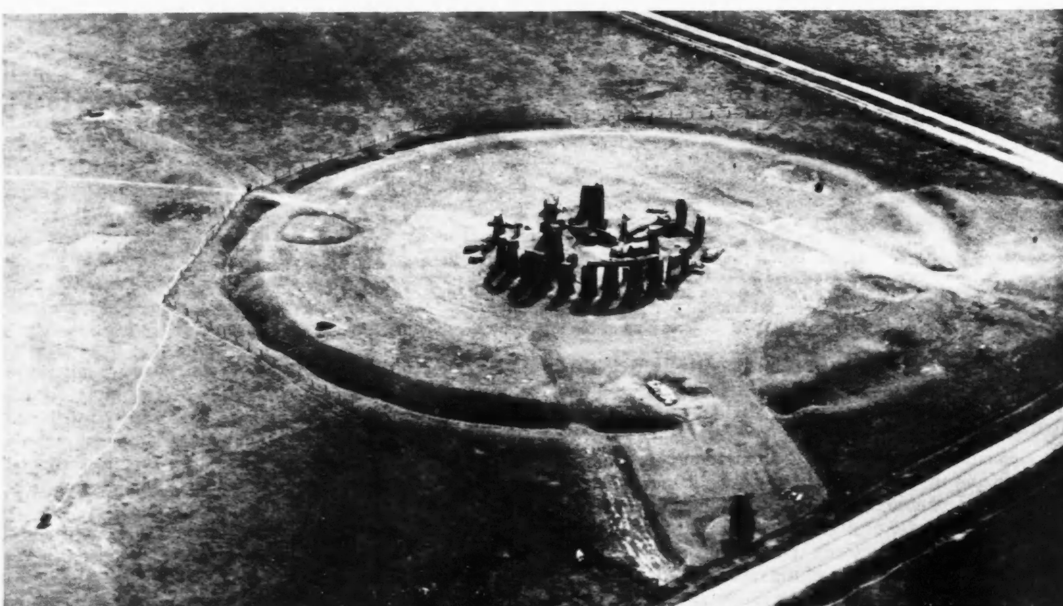


FIG. 3. Aerial photograph of Stonehenge from the north-east. (*Photo by J. K. St. Joseph of Cambridge University; Crown Copyright Reserved; reproduced by permission of the Ministry of Works.*)

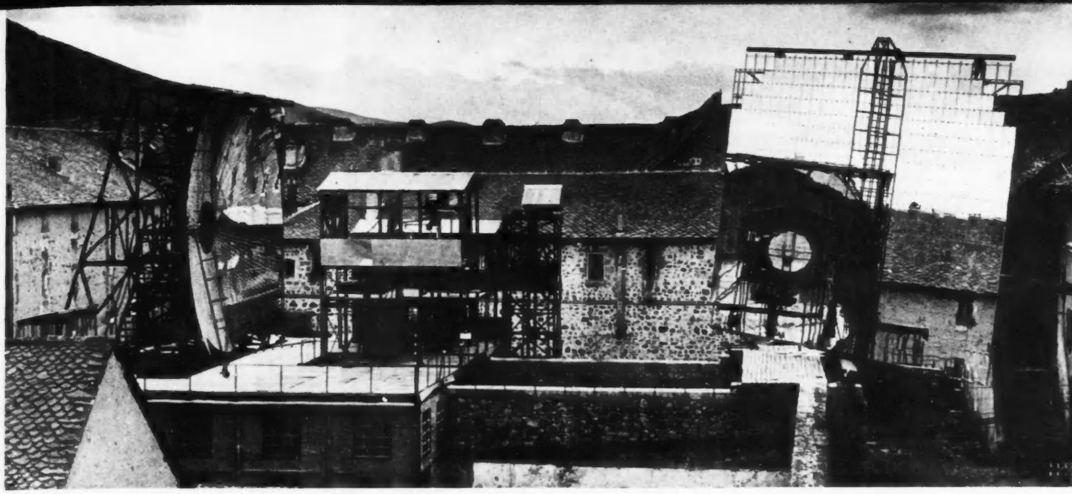


FIG. 1. Overall view of the installation at Mont Louis. On the left is the huge concave mirror, in the centre are the buildings where the main experiments are carried out with the terrific heat from the sun's rays. On the right is the reflector—a large flat mirror weighing 10 tons.

SOLAR ENERGY RESEARCH IN FRANCE

In 1950 the French National Centre for Scientific Research (Centre Nationale de Recherche Scientifique, CNRS) set up a solar energy laboratory. This was an official confirmation of previous years' research, which had indicated that it was possible to envisage the direct use of solar energy as a source of high temperatures. This laboratory is now situated in the citadel of the 300-year-old Fort Mont Louis, built in the French Pyrenees, by the great military engineer Vauban to keep out the Spanish invader.

Mont Louis was chosen because of its altitude (1600 metres above sea level) and the clarity of the atmosphere. It has at least 2750 hours of sunshine per year. Furthermore, solar energy reaches it at the average rate of 1000 watts per square centimetre; in autumn and spring the figure reaches 1100 watts.

The Director of the solar energy laboratory is M. Felix Trombe. In 1946, he set up a solar furnace at the Meudon Observatory near Paris, where he began experiments to capture and to concentrate the sun's radiation with the aid of optical apparatus. Making use of mirrors 2 m. in diameter and 85 cm. focal length, he was able to obtain temperatures of about 3000° C, and so used solar energy to melt a number of refractory metallic oxides and their mixtures, such as thoria, zirconia and lime.

His experiments had been supported by the keen interest of Professor Paul Lebeau, the Chairman of the Committee on the Chemistry of High Temperatures of the CNRS. In 1948, General Bergeron, Chairman of the Committee for Scientific Action in National Defence, became interested, and the result is that today this work on solar energy in France is the responsibility of General Bergeron's Committee and the CNRS.

When, recently, after having obtained permission, I visited the laboratory at Fort Mont Louis, I found the greatest optimism amongst the twenty scientific workers there about the techniques that have been developed. M. Trombe told me: "I have little doubt that within a few years the techniques we are developing here will be of considerable industrial importance."

The main apparatus at Mont Louis is a giant installation, made up of three parts. First there is an *orienteur*, which is a mosaic of 516 plate-glass mirrors giving in all the effect of a flat 43 by 43 ft. mirror. This follows the sun, moving under the guidance of a sensitive photo-electric system; this controls the movement of both on two axes, one horizontal, the other vertical.

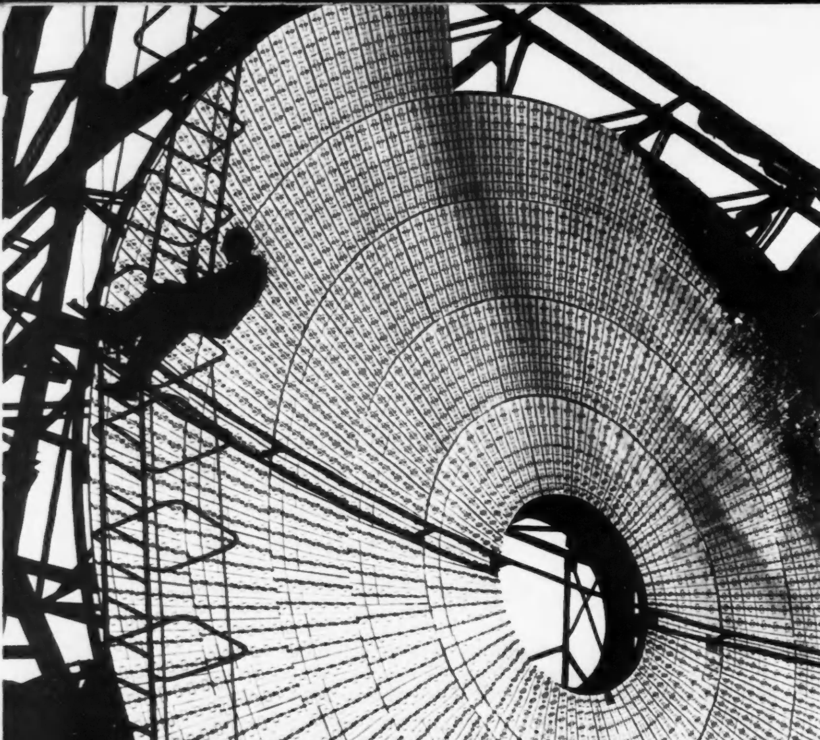
The sun's rays are deflected to a 31-ft. high and 33-ft. diameter parabolic mirror about 80 ft. distant. This again is not a single mirror, but is made up to 3500 mirrors which fit together to produce the overall effect of a giant concave mirror. The third essential part is a metal tower in which is placed the solar furnace. The furnace is exactly at the point of focus of the mirror, so that the sun's rays are concentrated there, giving temperatures of over 2500° C.

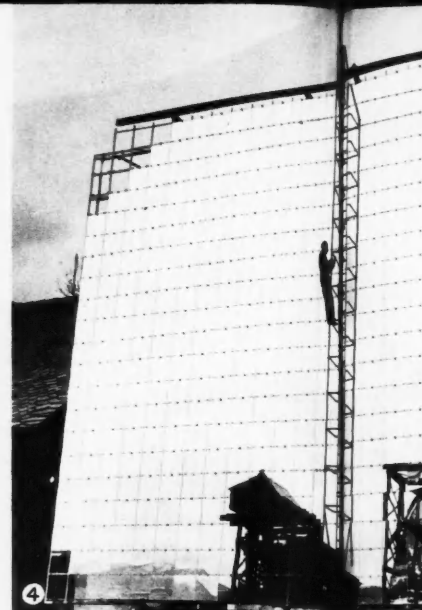
I was not able to see some of the specially designed furnaces in use, because these are regarded as secret, but the apparatus is said to be capable of handling many hundreds of kilograms of ultra-refractory oxides at a time. In a solar furnace it is possible to melt metallic bars; for example, masses of iron of about 100 or more kilograms. The iron melts at the rate of 60 kg. per hour, or half a ton a day.

The smaller installations at Mont Louis consist of former German ack-ack searchlight concave mirrors, which are used to produce temperatures up to 3000° C.

Whether the techniques employed are economic, I am not competent to say. Professor Trombe believes that in a short while he will be able to show that they are in so far as pure products and those that are at present costly are concerned. He has high hopes that in areas where there is continuous sunshine, and in the world's arid zones, his processes will transform the industrial scene.

The problems to be solved, said M. Trombe, still need a great deal of work. "That is why my team at Mont Louis is dealing with a great variety of research, ranging from those concerning the chemistry and physics of high temperature to those dealing with the improvement and the practical use of this new tool, which may be large or small, that we call the solar furnace." MAURICE GOLDSMITH





THE MONT LOU EXPERI

FIG. 2. The huge concave mirror—the bigg in the world—
on Mont Louis in the French Pyrenees. It ures 12 yards
97 square yards. Covering the surface are 3 curved pieces
weighs 12 tons.

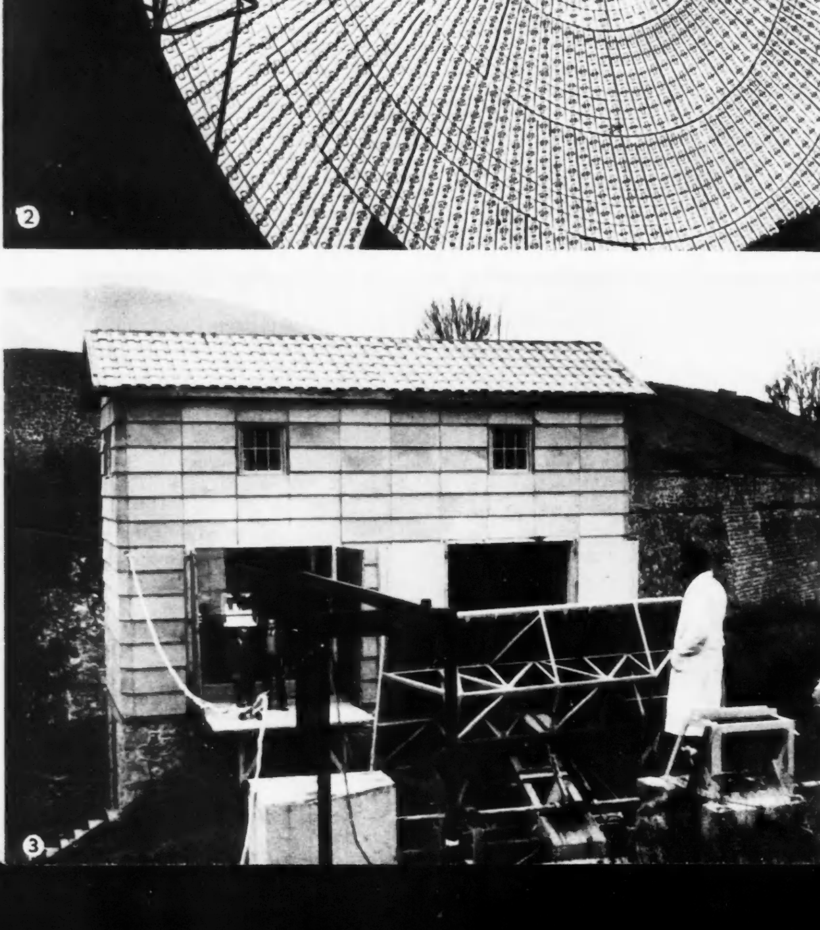
FIG. 3. These are the small installations w use German a
tures of up to 3000° C.

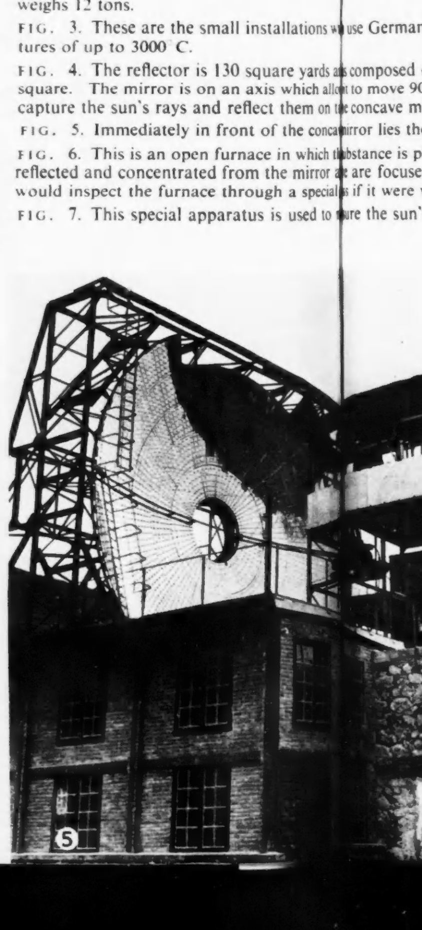
FIG. 4. The reflector is 130 square yards a composed of
square. The mirror is on an axis which allo t to move 90
capture the sun's rays and reflect them on t e concave mir

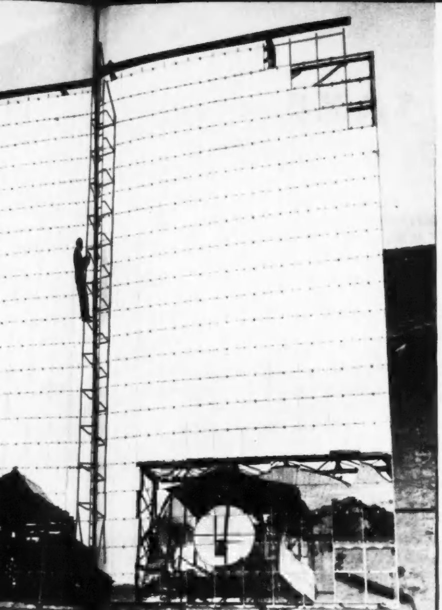
FIG. 5. Immediately in front of the conca irror lies the

FIG. 6. This is an open furnace in which t bstance is pla
reflected and concentrated from the mirror a e are focused.
would inspect the furnace through a special s if it were w

FIG. 7. This special apparatus is used to ure the sun's







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installations w use German ack-ack searchlights. Tempera-

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ace in which t bstance is placed and in which the sun's rays m the mirror a are focused. The researcher shows how he ough a special s if it were working.

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SCIENCE FOR ITS OWN SAKE

SIR EDWARD APPLETON

G.B.E., K.C.B., F.R.S.

This year's meeting of the British Association opened with the inaugural ceremony in the Philharmonic Hall, Liverpool, on September 2 when Sir Edward Appleton, F.R.S., delivered his presidential address, the major part of which was devoted to the theme "Science for its own sake".

The subject of my address, "Science for its own Sake", was chosen to emphasise something that, at times, is in danger of being overlooked, namely that science has interest as well as utility—that science is illuminating as well as fruitful. Having spent ten years of my own life in seeking to further the applications of science in the practical life of our country, I do not think I can be accused of under-estimating the vital importance of science as an instrument of material utility. I have long held the belief that the cost of scientific research is the price we must pay for our industrial progress. But we should be misleading the public, as well as ourselves, if we based our case for the general support of the pursuit of science on its utilitarian aspects alone. I know that we can claim that many discoveries in pure science, which in their time had no obviously practical import, have later proved to be the foundations of major improvements in our material civilisation. But even that is an argument of profit and loss, and, to my mind, does not bring us entirely to the heart of the matter. I should like to go back, beyond the achievements, to the example of the scientist—be he amateur or professional—who is impelled solely by a passionate desire to explore and understand. That is what I mean by science for its own sake—when knowledge and insight are sufficient reward in themselves. Can the pursuit of a scientific vocation of this kind be a way of living worthily? Can it, in Dr. Johnson's phrase, help to advance us in the dignity of thinking beings? What values for us as individuals does it propound? As well as theoretical knowledge, as well as material benefit, is there some deeper, if more intangible, thing, even wisdom itself, to be found in our vocation?

I certainly make no claim to be able to provide the right, or the only, answers to such questions. At the most I simply hope to indicate to you where I think *some* of the value of a scientific vocation lies. After the extravagant claims that have sometimes been made on behalf of science—claims which have had the disagreeable consequence of putting the scientist on a pedestal—it is well that we should walk humbly. And yet, all the same, in a time of uncertainty of values and lowering of ideals, it is important that we should own to what we believe.

Now I begin by attempting to get the setting right, by pointing out that we scientists do not really inhabit the kind of universe which has sometimes been attributed to us. Science has so often been accused of having reduced the beauty and mystery of the universe to something cold and mechanical. When science enters the door, enchantment, it has been said, flies out of the window. You will remember the lines of the poet Keats:

There was awful rainbow once in heaven:
We know her woof, her texture; she is given
In the dull catalogue of common things.

It is fairly easy to see how this attitude came about. The world of what is now called classical physics, as it was mapped out for us from the time of Newton onwards, had the advantage of appearing comfortably solid and tangibly final. Anyone, it seemed, who could understand why an apple falls from a tree could also understand the stars in their courses. In this light the universe might well seem to a poet to fail to come up to his expectations. We now know how misleading it was to regard this account of the matter as final. Perhaps the most striking fact about modern science, in its explorations ranging from the heart of the atom to the frontiers of the universe, is that, like poetry, like philosophy, it reveals depths and mysteries beyond—and, this is important, quite different from—the ordinary matter-of-fact world we are used to. Science has given back to the universe, one might say, that quality of inexhaustible richness and unexpectedness and wonder which at one time it seemed to have taken away from it. "The world will never starve for want of wonders", says G. H. Chesterton, "but only for want of wonder."

I hope to try to illustrate all this in a moment from the fields of cosmical research which have been my own interest for many years. But just now one general point I want to emphasise is that the scientific approach to things is a far more personal and imaginative activity than is sometimes realised. I am ready to admit that deliberate application to discovery can often take us some distance; also that important progress can result from the operation of a team of workers, as distinct from an individual, though this is mostly the case when the follow-up or consolidation of a basic discovery is in question. But the big jumps ahead are usually the adventures and intuitions of a single mind.

I need hardly remind such an audience as this that scientific activities are two-fold. We can make observations and experiments—that is to say, gather facts. And we can also seek to understand how the facts fit together. We express any order we can discern among the welter of facts in the form of a hypothesis or a theory. A theory, by the way, is only a hypothesis that has become, so to speak, respectable. But even then there is nothing final about it. As J. J. Thomson once said, a theory is a policy rather than a creed.

Now, even in this question of making observations, the scientific process is one which requires the fullest and subtlest employment of all our faculties. It demands, for example, that we should not only see things, but should notice them; and not only notice, but perceive them. Many a vital discovery has been nothing else than recognising the unexpected. To encounter nature in this necessary state of awareness is inevitably to find all its forms and movements, from the infinitely small to the infinitely large, full of inexhaustible significance and relevance. But even in experimental work it is the primacy of an imaginative idea or intuition that often starts it all off. In simple words, I might say that the important thing in experimenting is to ask nature the right question and in its most direct form. Only then is the answer clear and unmistakable. But so often one has failed to ask the right question and the terms of it have to be recast. In this complex process it is as if knowledge were playing a game of chess with the mind, and one has to be constantly on the alert with fresh tactics or even a changed strategy.

Many of our questions turn out to be wrong because they are unanswerable, but it is only by asking them at all that we eventually find we have asked the right one. And one knows how oddly, how unreasonably I might almost say, the right question has often flashed into men's minds. It was recorded by the German physicist Helmholtz that his best ideas only came to him when he was walking up a slowly ascending street—and significantly enough he was one of the founders of the principle of the conservation of energy! What I do know, from my own experience, is the fruitlessness of pondering over a scientific problem too long. The mind gets polarised and thought becomes captive to a groove. How often the best way of solving a scientific difficulty is to leave it alone! Also, speaking as a professional scientist who has only recently turned amateur, I would like to acknowledge the immeasurable debt which science owes to members of the latter category. My own subject of radio-physics has, on many occasions, been advanced by the observations of the gifted and enthusiastic amateur who was able to recognise the unexpected, even if his professional skill was insufficient to enable him to reveal its full meaning and implication.

Asking nature the right question in the right way—or recognising a theoretical pattern in a tangled skein of experimental data—often has the effect of introducing an element of beauty and elegance into the scientist's work. Do we not, on occasion, refer to a 'beautiful theory' and an

'elegant experiment'? It is perhaps a little difficult to say what precisely we mean by this. Not, I think, that the theory or the experiment is necessarily conclusive or irrefutable, or even particularly fertile in its consequences—that would be virtue of another kind. The quality I have in mind is that of inevitability—and yet, paradoxically enough, an inevitability which can cause surprise. A great experiment seems to us, somehow, something which could not have been done differently. Or, if it had, something essential would have been lost. We are surprised that someone thought of doing it that way but we can see now that that way is really the only way to do it. Taking away something, or adding something, only detracts from it. In this respect a beautiful experiment can surely be classed with a great work of art.

Now I have spoken in general terms of the scientist's approach to nature and of the kinds of mental quality and awareness that science requires in its followers. And I have tried to suggest that the exercise of these skills has a value in itself which is ample justification of a scientific vocation. To go further might be claiming too much. And yet, I wonder. If we think of the great figures of science and, to be fair, restrict ourselves only to those we have known intimately, can we not go further and say that the scientific vocation, by its very nature, calls for personal qualities that deserve to be recognised and honoured? I might point, for instance, to that tolerance and open-mindedness to new ideas which shines even from the printed page of Rutherford's Address to this Association when he was President here thirty years ago—that freedom from prejudice, muddle, hypocrisy and darkening of counsel which characterised the man many of us were so privileged to know.

And yet, in less serious vein—a vein to which Rutherford was as much addicted as anyone else—ought we not, as scientists, to try to see ourselves as others see us? Joseph Addison once declared that there was this at least to be said for natural philosophy, that it occupied the attentions of men, who, if they had pursued public affairs and politics with equal zeal and vigour, would have set the whole country aflame. While Dr. Hartley in his *Observations of Man* declares that "Nothing can easily exceed the vain-glory, self-conceit, arrogance, emulation, and envy that are to be found in eminent Professors of the Sciences, Mathematics, Natural Philosophy, and even Divinity itself. Temperance in these studies is, therefore, evidently required, both in order to check the rise of such ill passions, and to give room for the cultivation of other essential parts of our natures." And yet Adam Smith, in his *Theory of Moral Sentiments*, finds far more to say in our favour. "Mathematicians and Natural Philosophers," he says, "from their independency upon the public opinion, have little temptation to form themselves into factions and cabals, either for the support of their own reputation, or for the depression of that of their rivals. They are almost always men of the most amiable simplicity of manners, who live in good harmony with one another, are the friends of one another's reputation, enter into no intrigue in order to secure the public applause, but are pleased when their works are approved of, without being either much vexed or very angry when they are neglected. It is not always the same case with poets, or with those who value themselves upon what is called fine writing." I only hope we scientists can see ourselves in that mirror.

For specific examples of what I have called the pursuit of science for its own sake there is, of course, no shortage of material on which to draw. I have, however, decided to tell you the story of only one field of development tonight—a long short story if you like—instead of a number of short stories in brief outline. My story has been selected because it bears on what men think about the world rather than what they do about it, for it concerns the nature of certain objects in outer space whose nature has only been revealed in recent months. If I required a more homely title for my story it would be "Finding things out about places we can't visit".

From time immemorial men have examined the sky with their eyes, and found it to be populated with luminous bodies, the stars shining with their own, and the planets with borrowed, light. As time went on, telescopes were used to assist the naked eye, and in this way it was possible to see more feeble and more distant stars. Generally we may say that the bigger the telescope the more powerful it is in helping us to plumb farther into the depths of space. The 200-inch telescope at Mount Palomar can detect stars so far away that it takes the light from them 1000 million years of travel to reach us. In such cases the human eye is supplemented by the photographic plate which, through prolonged exposure, permits the photography of faint objects which can never be detected by the eye alone. In addition to the telescope the astronomer has also looked at stars with a spectroscope, by which the light from the stars is analysed into its constituent colours. In this way it has been possible to identify the kinds of atoms which exist in stars; since we know, from experiments carried out on the earth, how to recognise particular atoms by the particular colours—or wave-lengths—of the light they give out. We can call all observations of this kind optical astronomy since, in making them, we examine the optical light which comes from the stars.

Now it is of great interest to us here in Liverpool tonight to recall that it was Sir Oliver Lodge, one of the first professors in Liverpool University, who first thought of looking at the heavens with a 'radio eye' instead of with an 'optical eye'. The year was 1900, in the earliest days of radio, and Sir Oliver tried to discover whether he could detect radio waves from our own particular star, the sun itself. The experiment failed because of the insensibility of the wireless receiver used—it was the day of the coherer. Yet it would be no misnomer to call Sir Oliver the first radio-astronomer, for the experiment was surely conceived on right lines and, with modern valve equipment, would have commanded success.

However, it fell to an American radio-engineer, the late J. G. Jansky, of the Bell Telephone Laboratories, to discover that radio waves, as well as light waves, could be received from the heavens. One interesting feature of this discovery was that Jansky found all this out when he was looking for something else. But with impressive scientific awareness he was ready to recognise the unexpected. Jansky was primarily studying the direction of arrival of atmospherics, but he noticed a persisting hiss in his ear-phones when his directional aerial was aligned to receive from a particular direction, which he later showed was the direction of the stars in the Milky Way. The year was 1931.

Jansky, appropriately enough, was the first person to speculate on the origin of this radio noise from outer space. He pointed out that the most obvious explanation was that the radio waves came from the stars themselves and that we get the radio noise in strength from the Milky Way because a great population of stars is concentrated there. But when he came to test his hypothesis by looking for radio waves from our nearest star, the sun, he obtained a discouraging result. For, even with the equipment available in his day, he found, like Sir Oliver Lodge, that no radio waves were detectable.

Now it is one of the remarkable features of the history of this subject that Jansky's researches incited only a few sporadic observations in the way of repetition. During the Second World War, however, radar operators, using their sensitive equipment operating on wave-lengths of 5 to 10 metres, so to speak re-discovered the phenomenon. But that was a period when one had to distinguish sharply between the scientific things that were only interesting as distinct from the things that were really useful. Quite a number of other matters of purely scientific interest arose in the same way, but all one could do was to note them and shelve them till the war was over.

I can well remember how these various topics cropped up, during the war, in the discussions of a panel of young scientific workers of which I had the good fortune to serve as Chairman. This panel was really a small sub-committee, though it had a long name* and a distinguished parentage. It used to claim that, unlike most other war-time committees, its membership was confined to scientific workers and did not include officials. That I might have been classed in the latter category was generously overlooked. The task of the Ultra Short Wave Panel was to

* The Ultra Short Wave Panel of the R.D.F. Applications Committee of the Advisory Council for Scientific Research and Technical Development of the Ministry of Supply.

examine and interpret all the manifold vagaries of radar transmissions which were reported to it from operational experience and from *ad hoc* experiments. The Panel had to concern itself with many things including, for example, the profound influence of the weather on radio-wave travel in the lower atmosphere. The foundation of a new subject, that of radio-meteorology, was one result of its labours. That was a matter of practical moment. But the odd bits of information on radio-astronomy, though choice delicacies for a scientific appetite, had to be renounced. I have in mind here, in addition to the detection of radio noise from the Milky Way already mentioned, such subjects as the radar detection of meteors or 'shooting stars' and the detection—for the first time—of radio waves of violent intensity coming out of sunspot regions on the face of the sun.

Soon after the war, however, these matters became the objects of further enquiry and it is of much interest to note that radar equipment, developed in the first instance for the detection of aircraft and ships, proved extremely useful for this purpose, requiring only minor adaptations. Dr. J. S. Hey and his colleagues, S. J. Parsons and J. W. Phillips, for instance, made the first really detailed investigation of the amount of radio noise coming from different parts of the sky. For this purpose they converted a war-time radar receiver, which had been used in conjunction with anti-aircraft batteries, into a directional radio-telescope. Their work at once confirmed Jansky's original findings and showed that there was a close agreement between the intensity of the radio emission and the distribution of visible stars in the Milky Way.

Now I must digress from my main theme for a moment to remind you of a little of what is known about the distribution of stars in the universe as a whole. Our own solar system is really part of the Milky Way which is, itself, a colony or island of stars in space. This island colony has a structure like a magnifying glass, so that it is circular in shape but thicker at the centre than at the edges. You would not be far wrong if you thought of it as a Yorkshire tea-cake, the currants of which represent the stars. We inhabitants of one of the planets in the solar system do not occupy, however, a particularly privileged position in it, for we are situated nearer to the edge of the island colony than to its centre.

Space is, however, populated with far more stars than are to be found in our own Milky Way. But they are not distributed uniformly. They are grouped in island colonies exactly like our own. The astronomer calls these star colonies extra-galactic nebulae, and, with our big modern telescopes, it is possible to detect between 100 and 1000 million of them. The average distance between any one of these star colonies or nebulae and its nearest neighbour is about ten to a hundred times the size of either.

But I must resume my detective story about the radio noise from the Milky Way, for I think you will agree that it sounds much like a detective story as one clue after another is followed up. It was natural to assume at first that the radio noise coming from the sky represented the integrated radio effect of the stars in our own galaxy, since such stars are nearest to us. Our war-time experience concerning radio noise from the sun helped with the necessary calculations, for one could assume, as a first approximation, that all the stars would act like the sun. However, it turned out that there did not appear to be enough stars in the Milky Way to account for the high intensity of the radio noise. So then, as an alternative hypothesis, it was thought that possibly the noise came from the flying atoms and electrons which we know must populate the space between the stars. This was the inter-stellar matter theory. Unfortunately, here again, there were found to be difficulties. To account for the high intensity of galactic radio noise, when observed on the longer radio wave-lengths, required the ionised gas in inter-stellar space to be at a temperature of 100,000 degrees absolute, a value much too high to be reasonable. Also, we already knew that the inter-stellar material in question is concentrated in a narrow band near the galactic equator quite unlike the wide dispersal of both the stars in the Milky Way and the radio noise. So another theory had to be abandoned.

We had therefore arrived at this position, that the cosmic radio noise could not be accounted for as coming from the visible stars in the Milky Way or from the tenuous material existing in the spaces between the stars. However, this unpromising situation was soon relieved by an experimental discovery which, in its turn, led to others. Dr. J. S. Hey, observing the intensity of radiation from different parts of the sky, noticed that the strength of the radio noise from one particular direction—from a region in the constellation of Cygnus—occasionally showed rapid variations in a period of about a minute. At first it was thought that these fluctuations indicated variations in the emission from the source itself, but we now know that the variations are brought about by irregularities in the ionosphere, through which, of course, the radio waves must pass before they reach us on the surface of the earth. We can, in fact, look upon these variations as a kind of 'twinkling' introduced by irregularities in the atmosphere. But the most startling conclusion which could be drawn from these observations was that the source of this variable radio noise must be a very small one. In the case of visual light we all know that we can have a 'twinkling' star—because the star is a small source—but not a 'twinkling' moon.

Attempts were therefore immediately made to find out, by even more refined radio experiments, how big—or how small—in size this radio source in the direction of Cygnus actually was. There is no time to describe to you tonight the apparatus which was used, in Australia and in Cambridge, to test this matter but I can assure you that both experiments qualify for my adjectives 'beautiful' and 'elegant'. Both sets of investigators announced the same result, that the source in Cygnus was too small to have its size assessed with the equipment used—that is, that it occupied less of a tenth of a degree in the sky. However, in the course of the same experiments, the position of this powerful radio source was fixed pretty accurately. And maps of known stars were eagerly consulted to see if the Cygnus radio star, as we may now call it, coincided with any special visual emitter. The result of this examination was most significant for it was found quite impossible to identify the radio source with any particular star. Within the region which contained the radio star there were many faint visual stars to be found, but none of them seemed to exhibit any special peculiarities likely to associate them with the very powerful intensity of the radio emission.

Then, other parts of the sky were examined with the same apparatus and a further number of 'point' sources of radio waves were identified. One was found in the constellation of Cassiopeia, which was even more powerful than that in Cygnus. It also could be located with good accuracy. But, here again, there was no remarkable visible object apparent on the star map to connect it with.

It is important to pause here a moment to consider the effect of these observations on our outlook at the time. It was natural to ask a whole series of questions. Could it be that a radio star is always a dark star—and so a new type of object in the universe? If so, could it be that there was a duplicate universe—only to be seen with a radio-telescope as distinct from a visual telescope? And, as regards the overall phenomenon itself, could it be that the total emission of radio waves from the galaxy might be really the integrated effect of these dark stars, just as the diffuse band of light of the Milky Way arises from the unresolved radiation from distant optical stars? You will see that the tendency of the time was still to think of the radio emitters as being neighbouring bodies and inhabitants of our own galaxy rather than of other, more distant, island colonies or nebulae. However, a little reflection will show that we must not rule out the possibility of radio nebulae, as distinct from individual radio stars, even if we suppose that the greater part of our own radio noise comes from our own galaxy, the Milky Way. Any observer well outside the Milky Way should be able to detect the radio emission just as we, who are situated inside it, can do so. Such an argument received strong experimental support when a group of radio-astronomers in Manchester noted a relatively faint, but quite detectable emission, from the Andromeda nebula, which is a neighbouring stellar island colony of our own. Further work, at Manchester and Cambridge, has revealed appreciable radio emission from other nebulae not far from our own galaxy. It is clear that, in such cases, we are probably detecting their internally generated radio noise from the outside.

But the problem of the much more powerful sources remained. Where were they, why were they so powerful, and were they, basically, radio stars or radio nebulae? Again it was a case for more refined experiments which would enable their positions to be found with greater precision and give some notion of their sizes. I might mention here, in passing, that workers in Sydney, Australia, under the lead of J. G. Bolton, had already tentatively identified one radio star with the Crab nebula, a diffuse, expanding, cloud of gas which represents the remains of a stellar explosion which, according to Chinese records, took place on July 4th, 1054. So this was another radio source identifiable with a visible object, but it was of abnormal type, the 900-year-old relic of a supernova eruption.

The real attack on the identification of the two major radio sources, those in Cassiopeia and Cygnus, depended on the more accurate identification of their positions. In 1951 some new determinations were made by F. G. Smith at Cambridge and the results were communicated to the optical astronomers with an invitation to search afresh the parts of the sky in question. In the spring of 1952, a new and intensive optical search was therefore undertaken by Baade and Minkowski, at Mount Palomar, using the 200-inch Hale telescope and the 48-inch Schmidt telescope. As a result of this meticulous search, two entirely unknown objects were discovered in the universe. The Cassiopeia radio source was found to be associated with a diffuse cloud of luminous gas, situated within our own galaxy, and possessed of unique characteristics. The tenuous matter of which it is composed is concentrated in a number of fine filaments which are in the most violent motion. From a study of the colour of the light emitted by different parts of the same filament it is concluded that the velocities of such movement are of the order of several thousand kilometres per second. The origin of this gaseous cloud is unknown for it seems impossible to regard it as yet another supernova explosion.

The source in Cygnus, which you will remember was the one which first gave the clue to the possibility of radio stars, was found to be an entirely different type of object. Here the source of the radio waves was identified with another exceptional object which is considered to be two island colonies—two extra-galactic nebulae—in collision. Moreover, the distance away of this compound group of stars is estimated as being such that it requires 100 million years for the light and the radio waves generated in it to travel to us here on the earth. It is rather a humbling thought that it is only during the last sixty years of that travel that human beings have managed to learn how to produce radio waves and receive them. Now when a collision of two nebulae takes place it is considered that the stars of one island colony will pass freely between those of the other. On the other hand, the more extensive inter-stellar materials of the two island colonies will meet in collision, which will result in high excitation of the gaseous atoms of which this material is composed. One must suppose that, in both the radio source in Cassiopeia and the colliding nebulae in Cygnus, the high gaseous velocities give rise to this intense radio emission, although the detailed mechanism by which it all comes about is not understood. These identifications were finally confirmed by observations in Manchester, Sydney and Cambridge using still more refined methods of finding the sizes of these radio sources. The results of all three radio-observatories were gratifyingly consistent and were published simultaneously last December. In all cases it was found that the radio sources examined were definitely much bigger than simple stars and therefore corresponded to the sizes of the objects observed optically.

The accurate location of these radio sources in the universe—we must now, I think, drop the term 'radio stars'—has therefore led to new discoveries of great astronomical interest. Two unknown objects of unique character have been identified in the heavens, as a result of clues from the radio side; and it is to be expected that future accurate measurements of the positions of these cosmic radio emitters will lead, in turn, to the discovery of other visual objects of uncommon types. I should explain that the discovery of these rare objects by direct visual search with large optical telescopes would require quite prohibitive effort. The radio-telescope has therefore shown itself to be an important adjunct to the world's greatest optical telescope. But, in addition, there is a further and far-reaching possibility. It is the astronomer's ideal to reach, with optical ranging, the hypothetical limit of the expanding universe, the distance where the extra-galactic nebulae are receding from us with the velocity of light. So far he has reached very approximately half-way. But the fact that, already, the second most intense radio source can be detected without difficulty at a distance equal to one-tenth of the maximum distance plumbed by the 200-inch telescope suggests that it may, in time, be possible to detect sources at greater distances by radio than by optical means.

But, in any case, the more detailed radio mapping of the radio sources in the heavens must go on; for, as you will have gathered, we are still without an explicit solution of the original problem which started it all off, namely the rough overall correlation of the distribution of radio noise with the general structure of the Milky Way. Much progress in these matters can, I am sure, be expected from the operation of two large British radio-telescopes. Professor A. C. B. Lovell's group is constructing a large steerable paraboloid of 250-feet diameter at Jodrell Bank, a station of the University of Manchester, which will be the largest single radio-telescope in the world and available for a great variety of investigations; while the large interferometric radio-telescope, recently completed at Cambridge, for work by M. Ryle and his associates, is already yielding entirely new results in the detailed mapping of radio sources.

The radio-astronomical story is therefore far from being fully told, but even already one can record achievements in these three centres of Cambridge, Sydney and Manchester—partly in competition and partly in collaboration—worthy to be ranked with the greatest feats in the art of experiment.

I have only a few words to add by way of postscript. I have tried to show how science, pursued for its own sake, can enlarge men's horizons and invest the world with deeper significance. As an exercise we can claim it to be one of the most complex and far-ranging of our mental experiences. But we must not forget that there are other values and other experiences. At the opposite pole from our specific endeavour there are the ways of thought which do not change, whose concern is with what is *not* new, with the things that will not be superseded; and today we stand in need of these enduring and sustaining values of the spirit more than ever. We well know that, in the field of science, our work will in due course be probably outdated and certainly surpassed. At any one moment we may have only a precarious hold on a temporary truth and our consciousness of this ever urges us to seek fresh truths and new understandings. I fear that, in doing so, we may lose sight of other aspects of life which have their values, too. For, you know, there is a virtue in contentment, in being satisfied with what we already have, which we shall not learn from science. Our vocation, in other words, cannot be the whole of life for it cannot satisfy all our needs. Nevertheless, I hope I have represented it fairly as no unimportant or unworthy part of it. For we scientists are specially fortunate in this, that our vocation can never be simply an occupation; it is, by its very nature, more than that—a dedication to an end. It often seems to me that what we lack in the world today is not so much the impulse to dedication as the opportunity for it. This, at least, the scientist need never lack; the opportunity is open to him everywhere "to strive, to seek, to find and not to yield".

But we must still ask ourselves what it is that urges men to do these things and our answer must surely be that it is the challenge of it all. Why should anyone want to climb Mount Everest? Simply, I suggest, because it is there—as a challenge of the unknown and the unaccomplished—a challenge to spirit and body, now so gloriously met by Hillary and Tensing. In its different setting, the pursuit of science also presents to the human mind an enduring challenge on an endless frontier, quite apart from the material enrichment of mankind to which it may incidentally give rise. "The work may be hard, the discipline severe," as Lord Rayleigh said on an occasion similar to this, nearly seventy years ago, "but the interest never fails and great is the privilege of achievement."

THE BIOLOGY OF HUNTING SPIDERS

J. L. CLOUDSLEY-THOMPSON

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The diversity of the webs of spiders and the various and intricate methods that are used in their construction have always attracted attention. Indeed many people seem to notice only those spiders that capture their prey in webs, such as the much maligned, long-legged house spiders (*Tegenaria*) which spin cobwebs in the corners of rooms and outhouses, and the garden spiders (*Araneus*) whose dew-spangled orb webs glistening in the sunlight lend their beauty to the autumn morning.

The spider fauna of the British Isles comprises over 565 species belonging to 24 families, with a population that in late summer has been conservatively estimated at some 2¼ millions per acre. Dr. W. S. Bristowe, to whom we are indebted for this figure, has calculated that if all the spiders from an acre of land combined together to build one continuous thread, they would produce a strand in a single day's spinning that would just about circle the world at the equator: after ten days it would be long enough to reach the moon. The weight of insects destroyed each year by spiders in England and Wales well exceeds the total weight of the human population!

All spiders spin silk, but by no means all of them live sedentary lives in webs. If they did so, a large amount of potential food in the form of insects would not be exploited. In fact, the more primitive species use silk only for building their retreats and for weaving the cocoons in which they lay their eggs. Dr. Bristowe, our leading authority on the biology of spiders, has even suggested that predation by primitive hunting spiders upon early wingless insects may have been one of the main factors that engendered the evolution of insect wings. When their prey took to the air to escape, spiders evolved aerial webs as a means of trapping them in flight. As we shall see, however, the spiders that have remained true to tradition and actively hunt their prey are well adapted in a variety of ways to active pursuit.

Spiders are classified in families according to structural characters which are often correlated with the methods employed in the capture of their prey. Thus among those that do not weave webs we find Jumping Spiders (Salticidae)—small, rather squat animals with broad square heads, extremely large eyes and short stout legs—and Wolf Spiders (Lycosidae) with longer bodies and limbs and moderately large eyes. Like the related Pisauridae, these are essentially ground-living forms and the majority of them hunt in the open by day. Two other families of hunting spiders, the Oxyopidae and Sparassidae, contain species which are usually found in low herbage whence they leap down on to their unsuspecting prey.

Crab Spiders (which comprise the family known as Thomisidae) are sedentary types that wait on the ground or in flowers and vegetation for passing insects which are seized by the powerful outstretched legs. They frequently possess markedly cryptic (concealing) coloration; and the English name for this family derives from their habit of running sideways like crabs. The members of the Drassidae, Clubionidae and Anyphaenidae are mostly nocturnal spiders and move stealthily as they feel for their prey with front legs outstretched. (The members of all these families have eight eyes, but some other nocturnal hunting spiders belonging to the families Scytodidae, Dysderidae and Oonopidae have only six. The number of eyes is not such a fundamental character as was once thought, but it is still a convenient diagnostic feature.)

CAPTURE OF PREY

As we have seen, some hunting spiders seek their prey by day, trusting to their good sight, while others are active at night and depend mainly upon the sense of touch. Jumping Spiders (Salticidae) have the keenest sight of all, and stalk their prey from afar. This is one of the largest spider families, and includes several thousand species, which are mainly found in tropical countries where they almost rival the insects in the brilliance of their hues. Only thirty-two species of Jumping Spiders are on the British list, and most of these are rare and unlikely to be met with, except by the most energetic collector. Our commonest species is the little Zebra Spider (*Salticus scenicus*), so named because it is conspicuously marked with black and white stripes. Though less brilliantly coloured than some of its exotic relatives, it is an attractive creature often to be seen walking on walls and fences in the sunshine. Equally at home on a perpendicular surface or the underside of a horizontal beam, it is able to maintain its position by means of an adhesive tuft of hairs (the 'scopula') on each of its feet. As it moves the Zebra Spider trails behind it an exceedingly fine thread of silk, which is attached at frequent intervals like a climbing rope, so that in the event of a slip the spider does not fall to the ground. This spider has a curious way of exploring the surface on which it is working by successive short runs alternating with periods of absolute stillness. It will often patiently search a large area before it catches sight of an insect, when it can be seen to turn its head so as to bring its four large anterior eyes to bear upon the quarry. The four posterior eyes are smaller and less important. For a time it remains motionless, then begins to edge stealthily nearer until it is close enough for a sudden spring. The front pair of legs is used for seizing the prey and the remaining pairs for jumping. However, the jump is not always successful. Often the insect sees its peril at the last moment and flies away, and the spider has to begin all over again.

In contrast to the careful stalking of Jumping Spiders the Wolf Spiders (Lycosidae) run down their prey by sheer strength and speed. Some of the smaller species seem to be absolute wanderers and have no home at all, spending the night under any suitable rock or stone that they come across, whilst the larger kinds live in permanent burrows from which they never go far. Habits vary considerably. One handsomely marked species, *Arctosa perita*, is found in dunes of firm sand: and on heathland where the vegetation

has been burned away it makes its silk-lined burrows. Sometimes several of these spiders live quite close together in a colony. On the other hand, *Lycosa purbeckensis*, an inhabitant of salt marshes, survives the spring tides by carrying a bubble of air below the surface of the sea.

Although most Wolf Spiders frequent dry and stony places and are particularly numerous in the spring and early summer, the members of the genus *Pirata* are semi-aquatic, living at the margins of rivers and ponds, and are able to run on the surface of the water. *P. umbraticola* spins a silken tube in damp moss at the water's edge: it will run beneath the water if it is alarmed. The large *Dolomedes fimbriatus* (Pisauridae) also lives in swamps and ditches. It is sometimes called the 'Raft Spider' on account of a popular fallacy that it makes a raft of fallen leaves on which to float down-stream. To escape capture this spider will also run down a plant stem beneath the surface of the water. Some of its foreign relations catch tadpoles and even small fishes to eat. No obvious features indicate that the Pisauridae are spiders of the water, but they can run on the surface with a grace almost equalling that of a Water-skater (*Gerris*) and they can remain submerged for long periods if necessary.

The typical Crab Spiders (Thomisidae) are seldom seen by the ordinary observer, for their habits are retiring and many of them are rather small. They wait motionless for passing insects which are seized by the powerful out-stretched legs, and having buried their jaws in the head or thorax of the prey, they draw their limbs backward out of danger of the victim's bite or sting. Some species, however, are true rovers, hunting by day and passing the night wherever they happen to find themselves. Those that lie in wait often show a remarkable degree of resemblance to the colour of their background. One East Indian species spins a white patch of silk on the upper surface of a leaf. Lying on this, it looks exactly like the dropping of some bird on the leaf, and such droppings seem to be particularly attractive to butterflies!

Lynx Spiders (Oxyopidae) are handsome hunting spiders with keen eyesight and have become specialised for life on plants. They can run over vegetation with great agility and leap from stem to stem with a precision surpassed only by that of true Jumping Spiders. The only British example of this family is the rare *Oxyopes heterophthalmus*.

The remaining families such as the Dysderidae, Oonopidae, Drassidae and Clubionidae contain mostly short-sighted nocturnal hunters that depend upon the sense of touch and grapple with any suitable insect they come across in their wanderings. *Harpactea hombergi*, a small grey species common under bark, holds its victims with its tarsal claws while the large and formidable *Dysdera crocota* and *D. erythrina*, easily recognised by their red cephalothorax and yellow abdomen, feed mostly upon woodlice and lunge forward so swiftly that few of their prey escape. *Scotophaeus blackwalli*, the mouse-coloured house spider, often falls into baths and sinks and then cannot climb out. Like many other Drassid spiders and Clubionids it depends upon speed, while the ferocious *Drassodes lapidosus* immobilises its victims by swathing them in bands of silk.

Perhaps the most interesting method employed in the capture of insects is that of the rare *Scytodes thoracica*. This slow-moving yellow-coloured species squirts poisonous gum from its jaws whilst on the move after the manner of a cruiser tank spraying infantry with machine-gun fire.

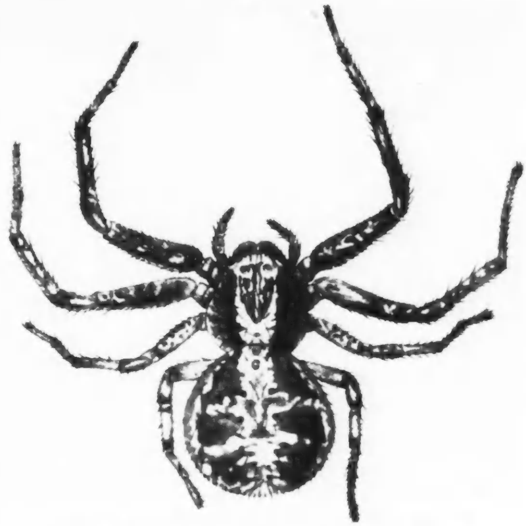


FIG. 1. The crab spider *Xysticus lanio*, female; a brown species found among trees and shrubs. Overall length, $\frac{1}{2}$ in. The smaller male protects itself in mating by fastening its wife to the ground by silk.

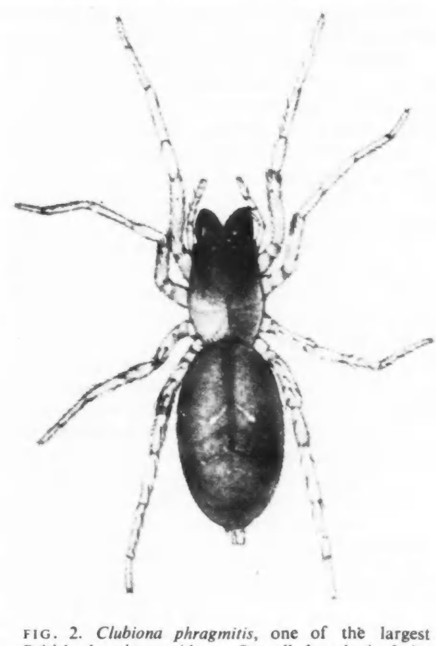
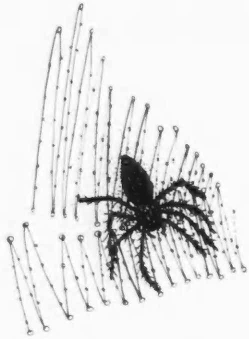


FIG. 2. *Clubiona phragmitis*, one of the largest British hunting spiders. Overall length is $\frac{3}{4}$ in. Found among marshes.



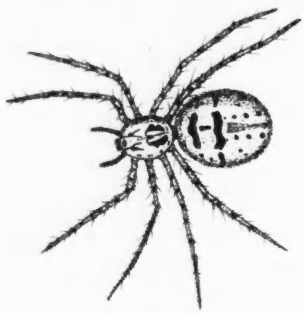


FIG. 3 (*left*). *Scytodes thoracica*, binding its prey with gum which it squirts from its fangs.

FIG. 4 (*right*). The best-known species of Jumping Spider, *Salticus scenicus*, with its zebra stripes.

The prey is stuck firmly to the ground while the spider advances and eats it at leisure.

ENEMIES

So far only one side of the picture has been considered. For in addition to the vast numbers killed as a result of unfavourable climatic conditions, spiders are beset with enemies throughout their lives. The infant mortality rate in particular is immense. Baby spiders do not feed until they have digested all the yolk in the eggs from which they hatch, but after their first moult the spiderlings develop their typical cannibalistic tendencies and many are eaten by their brothers and sisters. As Cecil Warburton once wrote: "The case of the survivor of the *Nancy Bell* in the Bab Ballads would be exceedingly commonplace in the araneid world."

Spiders and their eggs are also eaten by hosts of different kinds of animals. In this country the most important of these are probably toads and frogs, starlings and other insectivorous birds, shrews, wasps and centipedes. Invertebrate enemies are very much more numerous, and probably destroy larger numbers of spiders than vertebrates do, but spiders enter largely into the diet of smaller birds, being especially fed to the nestlings. Incidentally, many species of birds use spiders' egg cocoons to line their nests.

Social wasps often kill spiders to feed their larvae, and there are two British families of solitary digger wasps, the Pompilidae and Trypoxylinidae, which hunt spiders. The spiders are paralysed by stings, and are then dragged to previously prepared cells or burrows. After this the wasp lays an egg on each carcass and other paralysed spiders are added before the burrow is sealed up. These must provide enough food for the wasp grub when it hatches to last throughout the whole of its larval development. J. H. Fabre, W. G. Hingston and other naturalists have written graphic accounts of the habits of spider-hunting wasps. All kinds of spiders are attacked, although Wolf Spiders are perhaps the most frequent victims of the Pompilidae, and in the tropics even large 'bird-eating' spiders fall prey to these terrible foes. The first action of one of these wasps when it attacks a spider is to drag it into the open where it is nearly defenceless. It has been observed, however, that spiders appear completely panic-stricken when confronted by a digger wasp. Their immediate reaction seems to be to flee, and they do not try to defend themselves even when cornered.

The parasites of spiders include Protozoa and Nematodes, but there are few records in the literature. Infinitely more important, especially in tropical climates, are 'parasitoids' such as the ichneumons. These insects probably paralyse a spider by means of their sting before laying an egg on its back: although their most frequent victims are web-spinners, several different kinds of hunting spider have also been found with eggs or larvae on their backs. These larvae eventually cause the death of their victim by feeding on the contents of its abdomen. By some extraordinary instinct the larva does not eat the vital organs until last so that the spider does not die until the insect is ready to emerge from the now empty skin of its host. The Acroceridae (Diptera) are a family of flies which have evolved similar parasitic habits, and members of several other fly families are parasitic on the eggs of spiders. Apparently cryptic coloration and other protective devices are of little avail against these creatures, but even so, ichneumons and other parasitoids are a far less important factor in controlling the numbers of spiders than they are in controlling insect populations.

With so many terrible foes, it is not surprising to find that spiders have evolved all kinds of protective devices, including prickly spines, unpleasant flavour and scent: some even eject unpleasant fluids which deter predators. *Scytodes thoracica* squirts gum from its fangs for defensive purposes as well as when it is hunting. Many hunting spiders build silken protective cells in which they rest when not in search of prey. There is the interesting case of *Scotophaeus blackwalli*, which retreats with abdomen raised and trails behind it a ribbon of silk that serves as protection against attack from the rear. Many spiders achieve concealment by means of cryptic coloration, closely resembling their natural background, whether this is a coloured flower, a leaf, lichen, sand or bark; the Crab Spiders provide numerous fine examples of such camouflage.

Sometimes the outline of the spider is camouflaged by means of a 'dazzle-pattern', as in the case of the Zebra Spider whose irregular patches of contrasted colours tend to draw the attention of the observer from the shape that bears them. Egg-cases, too, are frequently effectively concealed.

Some poisonous and powerful species show conspicuous warning colorations, while all kinds of poisonous and distasteful insects such as ants, wasps, bugs, beetles and even scorpions are effectively mimicked by hunting spiders.

COURTSHIP

Spiders are nearly always on the offensive, and are ready to kill and eat most animals of suitable size which come close. They are inveterate cannibals, so it is obvious that mating must be a hazardous undertaking fraught with real danger, particularly to the male who is usually smaller and weaker than his intended mate. Indeed he will almost certainly be devoured unless he succeeds in allaying temporarily the carnivorous instincts of the female, and this he must do before he ventures within reach of her rapacious jaws. Dr. W. S. Bristowe has emphasised that it is of utmost importance to the male to establish his identity so that he is not treated like an insect victim, and thereafter courtship must proceed until the female has been stimulated to a state in which her sexual instincts have been aroused so that she will permit mating to take place. Consequently whichever of the senses is the one on which the species chiefly relies for the capture of its prey is the sense most employed in courtship. Male Jumping Spiders and Wolf Spiders make use of visual signs; short-sighted and nocturnal species of contact stimuli; web spinners use distinctive tweaks and vibrations of the threads of the snare, and so on.

The mating procedure of spiders is quite unique, for when the male reaches maturity he weaves a small pad of silk on which a drop of sperm is deposited and this is sucked up by the specially modified 'pedipalps' which in due course are inserted into the vagina of the female.

Courtship is a subject of great interest and importance and the literature on the subject is immense. I shall therefore confine myself to short descriptions of the mating habits of two species of hunting spider which I have studied.

The first is a tropical Jumping Spider, *Hasarius adamsoni*, which is found in many hothouses in Britain. The male is a handsome, squat, glossy black and brown spider with conspicuous white markings on the pedipalps, abdomen and distal limb segments. During courtship he advances slowly in zigzag fashion, waving his palps up and down. When the female, who is a sombre brown colour, turns towards him he stops and remains motionless with his large forelegs held horizontally above the ground as shown in Fig. 5. Then he moves forward again. As he nears the female he may jump rapidly sideways or backwards. Sometimes he dashes past her with great leaps. Again and again this display continues until at last he is permitted to insert first one and then the other of his pedipalps, and copulation takes place.

In contrast the nocturnal *Dysdera crocota*, which is my second example, has a very placid tactile type of courtship which apparently can be initiated by either sex. One spider approaches the other, quivering and gesticulating with front legs held aloft. During copulation the palps are inserted simultaneously and the two spiders stroke and caress each other with their forelegs.

In addition to the conspicuous antics just described, scent and chemical stimuli are probably involved concurrently during the courtship of all species. Many spiders stridulate

FIG. 5. *Hasarius adamsoni*; the male in courting attitude.

like scorpions, grasshoppers and crickets, and can thus make hissing sounds. A Wolf Spider found on Staten Island, Argentina, makes a curious purring noise at mating time by drumming on dead leaves with its palps. It is probable that in this case the female appreciates the vibrations at some distance.

LIFE HISTORY

Spiders lay their eggs in retreats and cocoons which they construct of silk, and often mount guard over them until the young have hatched. Wolf Spiders (Lycosidae) carry globular cocoons attached to their spinnerets wherever they go, and after hatching, the young climb on to their mother's back where they remain for several days. In the Pisauridae the mother spider carries her cocoon under her sternum; when the young are ready to emerge she fixes it to the end of a branch and mounts guard over it.

After hatching, a period of some days may elapse before the spiderlings scatter, during which, as we have seen, they eat little or nothing. The dispersal of young spiders of many species is achieved by means of 'ballooning'. The little creatures are carried aloft on a short thread of silk by upward-moving air currents. When large numbers are taking to the air and landing at the same time the accumulated silk produces the gossamer which clothes our fields in autumn. Those that survive the rigours of these perilous voyages and land in a suitable environment begin a life of toil and slaughter, of sacrifice and parental care which, for a small proportion of fortunate individuals, may culminate in the production of yet another batch of spiderlings.

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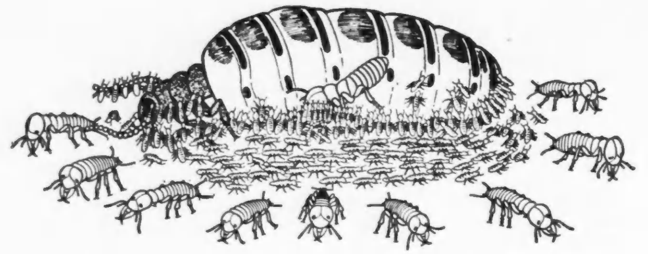


FIG. 1. Queen termite (of the species known as *Termes bellicosus*), with the king beside her and surrounded by attendant workers and a circle of soldier guards (*after Escherich*).

SOCIAL ANIMALS AND THEIR BEHAVIOUR

DEREK WRAGGE MORLEY

M.A., F.L.S.

The publication of two books such as N. Tinbergen's *Social Behaviour in Animals* and O. W. Richard's *The Social Insects** within a few weeks of one another calls for more than ordinary comment. The study of societies of living creatures whether they be insects, birds or human beings is one of the most fascinating of avocations, and to read the results of such work is always of interest. We are, of course, interested because we ourselves are social creatures, but that does not mean that the interest need be misplaced, nor a frivolous search for likenesses or metaphors. It can and should be directed towards serious, though enjoyable, observation and study.

There are certain common denominators in all types of social behaviour. One of these is the fact that it is only found in creatures where the young remain with their mothers (not necessarily with their fathers) at least for a considerable period of time after their birth, if not until they reach full adult maturity. In both the social insects and in man this association is continued, though in man often somewhat tenuously, through the whole period of life. This is of interest in view of the fact that it is in these two groups of creatures that the most highly developed societies are found.

Another phenomenon which is common to all societies, both poorly and highly developed, is the sharing of work. Solitary creatures may perforce, because they "share certain common needs or react in the same way to certain external stimuli", collect in large numbers in a small area, but as Richards points out, the solitary bees or wasps which form a dense population in a single earthbank "never help one another".

Basically the study of social behaviour is, as Tinbergen says, "the study of co-operation between individuals". It is the study of how and why and to what extent they share and play a dual role of action and reaction one to another, in the three main activities of life, courtship and mating, food-getting and fighting. It is at this point that certain differences become apparent. Man, for example, though too often bound by just such a triad of activities, has another equally important one—the development of his spiritual and intellectual nature. At the opposite end of the scale, the courtship and mating of the social insects is, though significant, of considerably less importance. The sterile ant workers are psychologically affected by the preparations for the marriage flight and its occurrence, and this is even more the case in the bees, but there is no complex courtship such as is found in many birds, or even in the stickleback.

The significance of the mating is reflected in the life of the social insects by the presence of the fertile queen (in bees, wasps or termites) or queens (in ants). In ants this has a particular importance because the grubs produce a sweet secretion which is extremely attractive to the workers, and much sought after by them. The ant queen is thus indirectly a producer of attractive secretions, and when she dies, the source of these dries up, which is probably the reason why the behaviour of the workers in a colony rendered queenless changes and becomes less seemingly purposeful. Richards omits to mention this important phenomenon, long since well established, and the keystone on which the structure of ant behaviour is laid.

A second major difference between the social life of the insects and that of other social creatures, is that in the insects the co-operation and division of labour is more or less confined to the workers.

Entomologists (and other biologists) writing about the social behaviour of insects have for too long side-stepped the issue of how this co-operation works, by saying it is physiologically determined by the occurrence of the structurally different castes of male, female, workers and soldier. Apart from egg-laying the real division of labour in, for example, the ant community, occurs amongst like individuals—the workers. Yet Richards accepts this plea of the physiological determination of what work is done and states that "if the workers have a uniform structure, then at different times they contribute to all the activities of the colony". According to him it would seem that only those ants which have soldiers, or exceptionally large and

* *Social Behaviour in Animals* by N. Tinbergen. (London: Methuen; New York: John Wiley, 1953, 150 pp., 12*s.* 6*d.*)
The Social Insects by O. W. Richards. (London: Macdonald, 1953, 219 pp., 15*s.*)

exceptionally small workers at the same time, show any real division of labour. Yet the species in which such forms occur are but a fraction of the total of ant species, and those not the most highly developed socially. Also Miss Buckingham and later Chen and others found little difference between the activities of the larger and smaller worker forms.

Perhaps it is for this reason that Richards believes that "it is very difficult to organise a society until there are elaborate means of communication and a brain capable of understanding what is conveyed". It is indeed if all the individuals are taken to be of like ability, and if division of labour is taken to mean the apportioning of rigidly fixed jobs so that one individual does one job, or one type of job, and never anything else for a definite period of its life, as in the bees, or throughout its whole existence. But in the first place ants can learn, and with differing individual ability (Schneirla), and work with differing activity and success (Chen), and in the second place that definition of the division of labour refers only to a special case. It is too confined.

The interesting point about the social insects is how the work is shared out so that a high proportion of the members of the colony stay at home and work, while others are out foraging. Here differing degrees of physical activity, and differing ability to learn, play an important part—all tasks may indeed be undertaken, but some are learnt better or first, and thus more habitually undertaken than others. Communication also is not a *sine qua non*—certainly there is little enough evidence for it amongst the ants—when the system of 'releasers' first described by Lorenz and so notably applied and extended by Tinbergen, is considered. Just as the fighting behaviour of the stickleback is released by the sight of the red underside of another stickleback, and the Herring Gull chick responds by begging to the red patch of colour on its mother's or father's beak, so in perhaps a slightly different way does the resting ant, jostled by another ant doing something, have released the response to set about doing that type of thing. It may set off to a different area to do it, but do it it will, unless perhaps it meets another ant doing something else that seems to have greater releaser value, which sets it off reacting in a different way.

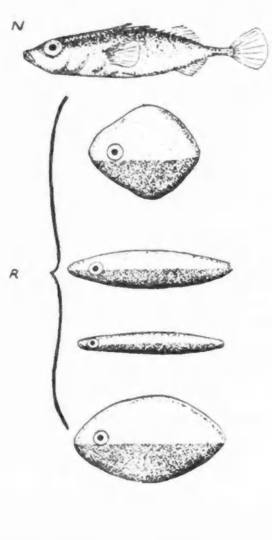


FIG. 2. An example of a releaser mechanism. A model (N) of a Stickleback, perfect in shape but lacking a red underside, releases no urge to fight when shown to a male stickleback. But the four models (bracketed R), all coloured red underneath, stimulate male Sticklebacks to attack despite their unnatural shape.

The dance of the bees which indicates the distance and direction of a source of honey would likewise seem to provide another example of the operation of releaser mechanism. We tend to think of honey-bees in terms of the species domesticated now through many centuries and known to have been kept for their honey by the Egyptians. But there are wild ones in the East like *Apis dorsata*, described by Richards, which likewise make a comb for storing honey and have a distinct worker caste. There are also stingless bees the world over, though more abundant in South America, some kinds of which like *Trigona* the Maya Indians domesticated long before the Spanish conquest of Mexico. Sections of hollow logs were used as hives, and apiaries of a hundred or more logs were kept. The legs of these bees are modified like those of the honey-bee for carrying pollen; their honeycombs have royal cells.

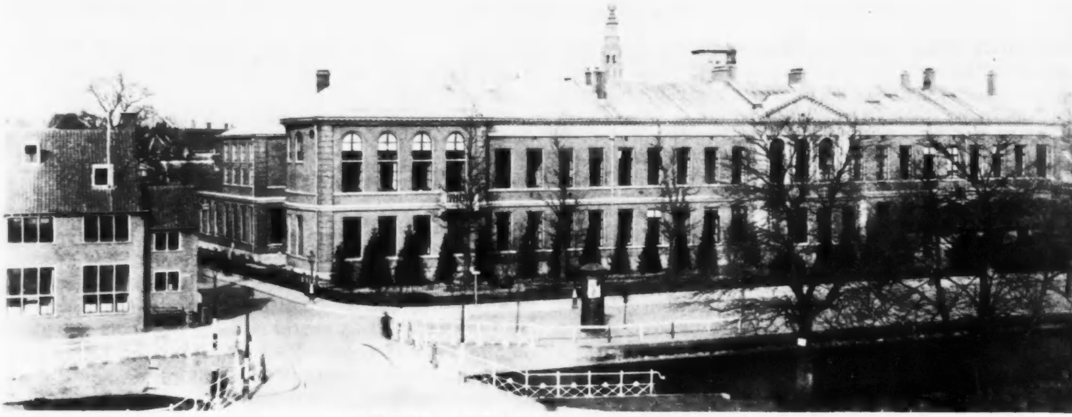
The story of the hunting wasp, *Philanthus*, which uses landmarks to find its way, is mentioned by both authors. Richards describes what happened when a circle of pine cones was placed round a wasp's burrow while she was inside it. When she appeared, she flew round and round the site for about six seconds studying the site before flying off in search of prey. In her absence the cones were removed and re-arranged about a foot away from the hole. Ninety minutes later on her return, she searched vainly for her nest in the circle of cones, but was quite unable to find it until the cones were replaced around the hole.

The life of wasps both solitary and socially is equally fascinating as that of the better-known bees and more exotic ants, with their fungus-growers, harvesters and slave-makers. For example, we learn in Richards' book that the temperature inside the nest of a thriving colony of wasps is usually 5–15°C higher than that outside, and that hornets are on the increase in England. Richards also gives much information about the termites with their concrete-hard 'sky-scrapers', and the giant egg-laying queens which, after their brief 'royal promenade' and eventual mating, are entombed with their royal mates in a central chamber for the rest of their lives.

Many species of termites, like the ants, have soldiers with large heads. These defend the colony in times of attack, and some have a long horn on their heads like a unicorn's spike, through which they squirt poison at their foes—usually marauding ants.

Both books are fascinating, and deserve to be widely read. Richards' account of the bees and wasps, on which he has done much important work, is particularly interesting. If Tinbergen's book is perhaps a shade more stimulating, it is because he seeks and finds the 'why', and if he doesn't as yet succeed, has a method and approach that he feels will find the answer. Indeed many biologists believe that this new attack which is felt in every page of his book will bear fruit, the counterpart in biology perhaps of the revolution in physics wrought by Rutherford in the golden years of the Cavendish.

From both comes a cry for more and more research, both in the laboratory and the field: "We know too little of this" is a plea that has to be repeated far too often.



The Kamerlingh Onnes Laboratory, Leyden

THE MAN WHO LIQUEFIED HELIUM

The centenary of the birth of Kamerlingh Onnes which falls on September 21, brings to mind all the painstaking researches and at times dangerous experiments carried out by academic scientists on the liquefaction of gases.

Onnes was born thirty years after Faraday first prepared liquid chlorine, and in the very year of discovery of the Joule-Thomson Effect in which a compressed gas suddenly expanding through a porous plug undergoes a fall in temperature. The Onnes centenary is an appropriate occasion to review the contribution which his brilliant work at Leyden made to the liquefaction of gases, and to the approach to absolute zero.

Compression combined with cooling of gases became the first method of liquefaction, which one readily applied to such gases as sulphur dioxide, chlorine and ammonia. Ammonia was the first in this field; in 1823 came Faraday's classic preparation of a few drops of liquid chlorine. Such preliminary attempts formed the first chapter of this new field or branch of science, particularly when allied with Pictet's 'cascade' technique, one in which a gas liquefied by compression and refrigeration is used in turn to cool a second more 'difficult' gas while the latter is also compressed. This cascade process, however, proved of no avail when applied to the so-called permanent gases like oxygen, hydrogen and helium.

It was discoveries of an 'academic' nature like the Joule-Thomson Principle of 1853 which set the stage for such successes as that of Onnes in liquefying helium after the eminent Dewar, Travers and Olszewski had failed with this intractable gas. The physicist Andrews had contributed one essential point when he showed that no gas could be liquefied until it had first been cooled to its critical temperature. Then a third 'academic' contribution completed the essentials in seeking to liquefy the permanent gases. It was found that hydrogen and helium show an unusual Joule-Thomson effect, the temperature increasing instead of falling in passing through the porous plug or expansion device. Yet at low temperatures the normal Joule-Thomson fall in temperature was found to take place: hence the discovery that for these gases there was an 'inversion temperature' to be kept in mind as well as a critical temperature. If hydrogen or helium could first be cooled by Pictet's cascade method or by adiabatic expansion (for example, expansion in an engine to do work), then below the inversion temperature the Joule-Thomson process would or should be able to effect liquefaction.

After Dewar's discovery of the vacuum flask (designed primarily to keep heat *out*) and his preparation of a whole pint of liquid oxygen, Linde and Hampson liquefied air on a large scale. Then in 1900 Travers prepared half a pint of liquid hydrogen. It seemed that all problems had been solved. Yet it was still to take considerable effort by Onnes to prepare liquid helium with the lowest boiling-point of all, namely 4·24° K.

Onnes, son of a tile-manufacturer of Groningen, had shown his prowess as student by winning a prize at Utrecht for an essay on the determination of vapour densities. He was inspired by the work of Van Der Waals on the continuity of the liquid and gaseous states to take up a subject which became his métier. His Cryogenic Laboratory at Leyden was built as research centre for low-temperature work, and it was this institution which eventually became "The Kamerlingh Onnes Laboratory". Onnes was ever a practical man, and during his investigations he developed gauges for high pressures and apparatus for measuring low temperatures. It was Onnes who discovered the superconductivity of metals at such temperatures.

In 1908 after years of such work he took helium prepared from monazite sand, compressed it and cooled it with liquid hydrogen to 15–16° K. and allowed it to expand. He used 20 litres of liquid hydrogen, and it was when the last bottle was being expended and after the helium had been pumped through the cycle twenty times that the gas finally became liquid. It was left to his successor Keeson to solidify helium *en route* to the absolute zero, this after Onnes had made five unsuccessful attempts to pass this last barrier. Yet Onnes with his liquid helium is rightly perpetuated in a world-famous laboratory.

M. SCHOFIELD

THE BOOKSHELF

The Elements of Nuclear Reactor Theory by S. Glasstone and M. C. Edlund (*New York, Van Nostrand; London, MacMillan, 1953, 416 pp., 35s.*)

This book provides an excellent description of the calculations, based on the diffusion approximation, of the critical conditions for thermal reacting systems. The book also includes four chapters giving an adequate introduction to the physical processes occurring in the reactor.

However, the publishers' claim that the last chapter explains the more rigorous transport theory is questionable; for example, the treatment of the calculation of the extrapolation distance is scanty. In this chapter, this extrapolation distance, i.e. the distance at which the asymptotic flux extrapolates to zero at a boundary, is calculated for a non-capturing medium using the diffusion approximation. The result of the exact transport-theory calculation is merely mentioned. Also, in the derivation of the solution of the transport equation in an absorbing medium, many of the steps in the mathematical argument are missing.

The important chapter on the General Theory of Multiplying Systems is very good; it contains a description of the use of various slowing-down kernels in the calculations for thermal systems.

This book should be welcomed as it represents a summary of the great amount of work which has been carried out on reactor theory, and which, up to the time of publication of this book, has been scattered over innumerable reports.

J. H. TAIT

Automation: The Advent of the Automatic Factory by John Diebold (*New York, Van Nostrand; London, Macmillan, 1953, 181 pp., 21s.*)

Several years ago a research group at the Harvard Business School produced a pamphlet entitled *Making the Automatic Factory a Reality*. In this book, the leader of that group, John Diebold, deals more generally with possible developments in automatic production and their probable impact on industry and on society.

The automatic factory is made possible by the development of computing machines capable of rapidly operating on information coded in the form of electrical signals, together with receptor devices which give such information about the physical characteristics of a system, and effector devices which, locally stabilised by negative feedback, can be used to alter these characteristics. The computer output can also be made to operate a recording device, such as an automatic typewriter. Thus it can be seen that computing machines, automatic factories and automatic offices merely represent different uses of the same general functional arrangement. The computing operations can be varied by a programme which may either be built into the computer or continuously supplied to it; and this programme can obviously be produced by a subsidiary computing operation. Although this sort of idea is undoubtedly in the author's mind, at no time does he make an explicit synthesis of the form given above, and this tends to make much of the presentation obscure. The chapter on information theory and computers, for instance, is vague and disjointed.

Although 'automation' is merely one further step in the continuing process of industrial mechanisation, the full use of these new techniques requires a critical examination of industrial processes and products from a functional instead of a structural view-point. It is the great merit of this book that it emphasises the importance of this process of 're-thinking'.

The author envisages a flexible type of automatic factory in which currently available machine-tool units, linked by automatic material-handling devices, would be operationally controlled by a digital computer. The same general arrangement could thus be used for a variety of products, in contrast to the single product 'factory machines' suggested by Norbert Wiener in his book *The Human Use of Human Beings*.

If, however, large numbers of standard products are to be made, or if variety is possible by assembling items selected from independently manufactured sub-assemblies, then it may be worth while to make these in specially designed 'factory machines'. Different economic systems would doubtless favour different solutions, but it would also be important to consider various limitations of technological development such as the obsolescence of plant and products, and the scarcity of certain raw materials. The author's treatment of this important aspect of 'automation' is inadequate, and shows both his own pre-occupation with the American economy and failure to carry 're-thinking' to its logical conclusion.

The small section on the probable social consequences of 'automation' is, on the whole, well done, although here as throughout the book, discussion is limited to its effects on American society. Some interesting descriptions of various types of American equipment, actually used for handling information and materials, are given.

Provided that one bears in mind the limitations described above this is a timely and stimulating book.

H. D. TURNER

Aeronautics at the Mid-Century by J. C. Hunsaker (*Yale University Press; London, Geoffrey Cumberlege, Oxford University Press, 1952, 116 pp., 46 illus., 20s.*)

In 1913 a young American, J. C. Hunsaker, was sent by the Smithsonian Institution on a tour of European aeronautical research centres to study wind-tunnel design and operation, so that on his return he could supervise the construction of one of the first wind tunnels in the United States. (This tunnel was built from plans supplied by the National Physical Laboratory, and the balance was constructed by a British instrument manufacturer.) Professor Hunsaker, now retired Head of the Department of Aeronautical Engineering at the Massachusetts Institute of Technology, and Chairman of the American National Advisory Committee for Aeronautics which employs several thousand aeronautical scientists and engineers, is therefore well qualified to review the status and impact of aeronautics in its fifty years of development since the Wright Brothers' first flight in 1903. In this book he has not attempted to give a popular explanation of the technicalities of flight, but is concerned more with the adjustments which society has had to make and will have to make to the new mobility which the aeroplane has given. Naturally the accent is placed on U.S. work and aircraft.

The first chapter covers historical topics, and ranges from the efforts of the early pioneers to guided weapons and the possibility of nuclear-powered aircraft. Because of his scientific background, Professor Hunsaker often discusses the relative parts played by fundamental research and bold development, emphasising that even if short-term results from particular developments are impressive the background must always be the guidance for basic aerodynamic research.

The next chapter is concerned with air transport, the statistics of which are reviewed, and reference made to such matters as air safety, the human factor, the automatic control of aircraft, airports and aids to landing. With regard to private flying, the author feels that there is no basis on which to expect the tremendous increase in this 'flying for fun' which at one time was expected to materialise.

The final chapter is of most general interest, as it deals with the social and political effects of aeronautics. The growth of aeronautical research in the United States is described, but no mention is made of the fact that the N.A.C.A., which Congress established in 1915, was closely modelled on the British organisation set up by Lord Haldane in 1909. The criterion which Professor Hunsaker applies to prove the effectiveness of the efforts of the N.A.C.A., "the acknowledged superiority of the aircraft designed and produced by the American aircraft industry", is open to dispute and seems somewhat incompatible with statements elsewhere in the text concerning air transport by either jet propulsion or turbo-prop aeroplanes, where the only examples that can be quoted are the British Comet and Viscount. Incidentally his photographic illustrations of modern high-speed aircraft are mainly British, including the Swift, the Hawker Hunter and the Avro Delta. Nevertheless, it is perfectly true that the N.A.C.A. has indeed produced an immense amount of useful research data.

This most interesting book covers a huge field in a few pages, and ably conveys to the general reader the many complex factors which have contributed to the giant strides made in aeronautics in a half-century.

The Tools of Social Science by John Madge (*London, Longmans Green & Co., 1953, 308 pp., 25s.*)

The English literature on method in the Social Sciences is slight and this publication is evidence of the renewal of interest in Sociology.

Mr. Madge, a sociologist who has been associated with the D.S.I.R.'s Building Research Station, has set out to describe some of the techniques of some of the social sciences, to argue a philosophical point of view and to make a case for the participation of the social scientist in solving the problems of "this tormented world".

These several aims are not always compatible and make for unevenness in the quality of the work, especially as much of the research upon which the author relies for illustration has been done by scholars whose outlook is very different from his.

Mr. Madge has chosen to write about 'Social Science' and not about Archaeology, Anthropology, Sociology, Social Biology, Social Medicine or Economics. This has resulted in a discussion of particular methods and an argument for some methods, especially social experiment without much reference to the theoretical structure of the Social Science concerned or its level of development. He concentrates most of his interest on some aspects of Social Psychology and neglects Sociology, the study of Institutions, the Family, the State, Public Justice, Religion and the like, where experiment is impossible.

The author's occasional whimsicalities do not help the student. Thus he classifies persons who are to be interviewed into "potentates", "experts" and the "people" and misses the opportunity to discuss the need to understand the structure of any social group before attempting to study it. Again, by describing large-scale studies of fact and opinion, especially sample surveys, as "The Mass Interview" he confuses the reader. The one thing the subjects of these studies are not, is massed or kneaded together, in fact a major preoccupation of field workers is often to prevent their subjects meeting and discussing the study whilst the research is in progress.

As a guide to the intending research worker the book has the defect that much of what is described has been read about rather than experienced, and the accounts of techniques are too brief for the non-expert.

DENIS CHAPMAN

Climate and the British Scene by Professor Gordon Manley (*London, Collins, 1952, 314 pp., 41 colour photographs, 40 half-tones, 75 maps and diagrams, 25s.*)

To most of the inhabitants of the British Isles there is no such thing as climate: but upon the subject of the weather, at any time and in any place, the natives can become unusually loquacious. This national characteristic, indicating in most cases an inherent cautious optimism based upon sound observations of the elements, was probably one of the most important factors which led to the remarkable growth of meteorology in this country over the past three centuries. 'Wind book' observations were started at the Admiralty in the reign of Elizabeth I, and in the years between Britain has played a leading role in the sciences of meteorology.

In the present book Professor Manley interprets our climate to the man in the street. After reviewing the work of the early climatologists and giving a summary of British climatic data, the author proceeds to analyse the elementary properties of our moist atmosphere. From fogs, precipitation, lapse rates, etc. the reader is led gently through the fundamental concepts of the science, which are treated simply, without a mention of entropy, for example. This essential preliminary is followed by a concise interpretation of the atmospheric circulations over these islands, and the all-important neighbouring seas, before the component frontal systems of the ever moving series of depressions across the eastern Atlantic and these islands are described. Many of the synoptic maps illustrating this section are very modern.

Winter, the season of howling winds, clear frosty nights and sparkling days, marks the beginning of the climatological year. The changes of sky, temperature and the air circulations which contribute to the make-up of the British scene are described in masterly fashion. After the wild changes of winter come the brighter tones of spring, when the deep flowing rhythm of life reasserts itself, and depressions move more frequently and boisterously across these islands. In this season, which the author links very conveniently with early summer, so many of the activities of the countryside are linked with the climate and weather. The variable climatic conditions of this time of year he fully explains, and in terms easy for the layman to understand. The same is true of the third convenient grouping of the seasons, of high summer and autumn: here the author has very successfully achieved the difficult task of interpreting the influence of so many variable factors upon the climate of these islands. The treatment of the subject is far from elementary, but the author's lucidity and his introduction of typical 'synoptic situations' make this section of the book fascinating reading.

From the seasons the author moves on to the influence of topography and to a lesser extent of industry upon our weather. This is more than a general survey, since it contains examples of micro-climatic conditions affecting many aspects of our lives and is illustrated from recent researches.

Next follow chapters on mountains and moorlands, of snow and ice upon which Professor Manley is particularly suited to write. Finally there are chapters devoted to past British climate, instrumental records, climate and man, and climatological data. Although the glacial condition affecting this country are admirably described it is unfortunate that many of the excellent coloured plates, such as those of Loch Achtriochtan, contain nothing in the caption to show that these magnificent examples of the modification of topography by ice took place during the glacial periods. One gains the impression from these last chapters that the author would have liked to have had much more space in which to cover this well-trodden ground.

This is a book which makes a very welcome addition to scientific literature. It is extremely well written, lavishly illustrated both in maps, diagrams, black and white photographs and coloured plates. It interprets our British scene, the richness of our lands and the ever changing beauty of our landscape from the climatologist's viewpoint.

F. A. HENSON

Between Pacific Tides by Edward F. Ricketts and Jack Calvin. Revised by Joel W. Hedgpeth (*U.S.A., Stanford University Press; London, Oxford University Press, 3rd edn., 1952, 502 pp., 48s.*)

The first thing that strikes one about the third edition of this now almost famous book is the reduction in bulk weight. The second edition, published in 1948, was uncomfortably thick and heavy; the present edition, thanks to the use of a thinner paper, is reasonably manageable. To those who use the book in the field this reduction in mass will be a most welcome feature. They will welcome also the new section dealing with intertidal zonation and related matters, wherein is incorporated a considerable number of new drawings of Pacific coast marine algae. The main text is substantially unchanged but wherever needed has been brought up to date by the insertion of new paragraphs and the occasional re-writing of old ones. The very useful systematic index and annotated bibliography show evidence of careful revision. There is also an all too short account of the talented but eccentric senior author who died as the result of an accident in 1948. Most of the original illustrations are retained and there are some new ones, amongst which a few photographs by Mr. Woody Williams deserve high praise. One hopes that the next edition will include more of his work. The new endpapers give a useful sketch map of the Pacific coast of the United States, marking the locations of seven marine biological stations. Dr. Hedgpeth has accomplished his task of revision well.

There is much in this book to appeal to the English reader. Although the animals and plants are different species from those of our own coasts the general biological principles of seashore ecology are much the same the world over. The serious student of European shores cannot fail to profit by a careful perusal of this erudite work of Pacific natural history.

D. P. WILSON

Far and Near

Night Sky in September

The Moon.—New Moon occurs on September 8d 07h 47m, U.T., and full moon on September 23d 04h 15m. The following conjunctions with the moon take place:

September				
1d 16h	Jupiter in conjunction with the moon	Jupiter	4°	S.
5d 03h	Venus ,,	Venus	0·3°	N.
6d 17h	Mars ,,	Mars	3°	N.
11d 22h	Saturn ,,	Saturn	8°	N.
29d 03h	Jupiter ,,	Jupiter	4°	S.

The Planets.—Mercury rises at 4h 40m at the beginning of the month but is then too close to the sun to be observed and is in superior conjunction on September 7, after which it becomes an evening star but remains too near the sun for observation. Venus rises at 1h 55m, 2h 30m, and 3h 10m on September 1, 15, and 30, respectively, stellar magnitude $-3{\cdot}4$ and the visible portion of the illuminated disk varying from 0·78 to 0·86. Mars rises about 3h 30m during September and moves eastward in the constellation Leo; about the middle of the month it lies a little north of the bright star α Leonis (Regulus). Jupiter rises at 22h 45m, 22h, and 21h on September 1, 15, and 30, respectively, stellar magnitude about -2; its slow eastward movement from north of ζ Tauri in the early part of the month towards the constellation Gemini is easily detected. Saturn sets at 20h 15m on September 1 and at 19h 20m on September 15—a little more than an hour after sunset—and draws too close to the sun to be observed at the end of the month when it sets 45 minutes after the sun.

A number of stars in the constellation Taurus will be occulted by the moon in the morning hours of September 27, from 2h 31m till about 4h 58m. While none of these stars is very bright the occultations could be easily observed in the absence of bright moonlight, but as the moon is full on September 23 binoculars will be necessary to observe the occultations. The moon will be seen approaching the stars in its eastward movement and the stars will disappear behind its eastern limb (its limb on your left as you face it). The stars vary in magnitude from 3 to 4·2. Autumnal equinox occurs on September 23d 08h.

Experimental Transmitter for Television Students

The Television Society has built an experimental 405-line transmitter to operate on 427 mc/s with a peak power of 12 watts. The equipment is being installed at the Norwood Technical College, which makes a speciality of telecommunications courses. In addition to providing a test signal for the society's members interested in U.H.F. reception, it will serve as a demonstration for students attending the television training classes in the college.

With the call sign G3CTS/T, it was expected to be on the air by the end of last month. The transmitter will be exhibited at the Radio Show.

The society also has under consideration a 625-line transmitter, which will be designed and operated in collaboration with the radio industry. This will enable commercial receivers built to continental standard to be tested under working conditions.

It is not intended that either transmitter shall be operated as a commercial station, and their construction has been undertaken as part of the society's policy of aiding the development of television technique.

British A-Bomb Test

It has been announced that the next British atomic test will take place this October on the Woomera rocket range in the S. Australian desert.

British Woodlice

A complete key for the identification of the genera of British woodlice, as well as short systematic description of all the individual species is provided in a paper contributed by E. B. Edney, of the Zoology Department of Birmingham University, in the latest number of the *Proceedings of the Linnean Society* (Vol. 164, Pt. 1, pp. 49–98). Some 35 species are included, some of which are foreign ones only recorded from Kew and other botanic gardens, where they have been able to survive for a time under the artificial conditions existing in hot houses.

Research on Glasshouse Crops: New Institute to be Established

The Minister of Agriculture is establishing a new independent agricultural research institute to promote research on the cultivation of glasshouse crops and mushrooms, and of bulbs, flowers and shrubs grown in the open. A site has been acquired at Toddington, near Littlehampton, Sussex, and eventually all the staff of the Cheshunt research station in the Lea Valley (established in 1913) will move into the new premises at Toddington.

The first chairman of the institute's governing body is Mr. T. Ainslie Robertson, chairman of Plant Protection. The institute's director is Dr. W. F. Bewley, of Cheshunt.

Depository of Unpublished Mathematical Tables

From time to time scientists work out mathematical tables which would be useful to other scientific workers, but which do not justify printed publication. The Royal Society has a depository of such tables, information about which can be obtained from the society's Assistant Secretary, Burlington House, London, W.1.

The new Director-General of Unesco, Dr. Luther Evans. He established his reputation as an administrator as Librarian of the U.S. Congress, a post which involves handling a larger staff and a bigger budget than that of Unesco.

An L.C.C. Research Fellowship

Each year the London County Council awards a fellowship—known as the Robert Blair Fellowship in Applied Science and Technology—which enables one of the L.C.C. staff connected with technical colleges to take twelve months' leave of absence and devote the period to research work. This year's award has gone to Dr. J. T. Stock, head of the Chemistry and Biology Department at Norwood Technical College. Dr. Stock's particular interests lie in the fields of microchemistry and electrochemistry, and his 'sabbatical year' will be spent in the U.S.A. doing research into the analytical aspects of these two subjects.

Increasing Terylene Production

I.C.I. have decided to double the size of the Terylene fibre plant now being built at Wilton, Yorkshire. The original plant, with a scheduled capacity of 11 million lb. per year of filament yarn and staple fibre, is due to commence operation early in 1955. The new extension will be ready a year later.

For the past three years the supplies of Terylene have been limited to the output of the pilot plant near Fleetwood.

Dr. Julian Huxley is awarded £1000 Popular Science Prize

Dr. Julian Huxley has been awarded this year's Kalinga Prize for popular writing in science. This annual prize of £1000 was

RESISTANCE TO SELECTIVE WEEDKILLERS

The discovery of DDT-resistant strains of flies brought the realisation that the continued use of the insecticide can bring about an increase in the proportion of flies in a given population which are resistant; here the DDT acts as a selective insecticide which favours the DDT-resistant strains as against the ordinary strain. The way out of the paradox is to apply a different kind of insecticide (e.g. Lindane) once the presence of resistant strains is detected. Experts on selective weedkillers have been watching for a similar effect to arise; but according to Prof. G. E. Blackman of Oxford University in a recent lecture to the Farmers' Club no case of resistance among species of weeds susceptible to weedkillers has yet been found. He said, however, that the fact that there are marked differences in the varietal reactions of several crops to herbicides suggests that there is a real danger of such an effect occurring. He recommended ringing the changes with the different herbicides that are available —"variation in the herbicides employed is sound herbicidal practice, particularly on farms where the dominant weeds are not capable of being eradicated by a single compound," he said.

He referred to the way bacteria in the soil destroy the two selective weedkillers MCPA (2-methyl-4-chlorophenoxyacetic acid) and DCPA (2, 4-D). He cited the researches of Prof. L. J. Audus of Bedford College who has shown that when either of these is added to a soil for a time nothing happens; and then very quickly at the end of some 14 days for DCPA or 50–60 days for MCPA the compound is very rapidly decomposed. If after the decomposition is complete, a further quantity of the compound is added, then this time there is no lag phase for the decomposition starts immediately. Just how long the specific population is maintained in the soil in the absence of further additions is not yet known but the experiments show how efficiently the micro-organisms can be mobilised to deal with compounds which have only been known to man for a dozen years.

He referred to the precautions that must be taken by agricultural users of toxic chemicals, and to the two herbicides known as dinitro-ortho-cresol (DNOC), dinitro-secondary butyl phenol (DNBP). He said he knew of no case where stock had been killed by these compounds, and described their danger to birds as "very small"; the decision must rest on the individual farmer "as to whether he opts for the birds or a weedy crop".

"All that can be added is that DNBP is still the most effective material for weed control in peas and seedling lucerne and for the time being I at least see no prospect of its replacement with less toxic materials. Similarly, in cereals, DNOC remains the best treatment for a number of important weeds like corn marigold," concluded Prof. Blackman.

(Director of the D.S.I.R.'s Pest Infestation Laboratory) described an unusual method of asphyxiation by carbon dioxide. According to the report of the Conference in *Food Manufacture*, he said that workers in the Argentine had found that when large concrete underground storage pits, specially treated so as to be impermeable to oxygen, carbon dioxide and water vapour, were filled with infested grain and sealed over, e.g. with roofing felt and bitumen, the respiration of the insects caused a rapid rise in carbon dioxide concentration and a corresponding fall in oxygen tension, with the result that the insects were asphyxiated by their own efforts. Information on this development was brought back to this country by Dr. Turtle, of the Ministry of Agriculture and Fisheries, and it was realised that it might be of great value to certain colonial territories for the long-term storage of grain. Trial pits had been built and tested in parts of E. Africa with promising results and it was likely that the method would be developed on a full commercial scale.

Another method by which the need for insecticides could be avoided, or at least minimised, was the self-sterilisation of bagged grain. By stacking bags in the tropics as tightly as possible in order to conserve all the heat that might be engendered, much of the insect life in the centre of the stack was killed, or was driven to the periphery where contact insecticides could be used in the form of dusts applied to the outer bags. This method has been successfully used on a large scale in E. Africa.

established in 1951 as a gift to Unesco from Mr. B. Patnaik, Indian industrialist.

The jury for the 1953 award was composed of Dr. M. N. Saha, professor of physics at the University of Calcutta, Mr. Paul Gaultier, Member of the Institut de France, and a well-known editor and publisher, and Professor A. J. Kluyver, Technische Hoogeschool, Delft.

The Dehydration of Meat

A monograph entitled *Dehydrated Meat* (H.M.S.O., 6*s*.), by Dr. J. G. Sharp of the D.S.I.R.'s Low Temperature Research Station, has just been published. This gives a considerable amount of detailed information about the technique of dehydration. It states that by the end of the last war the principal meat-producing countries of the world (excluding the U.S.A.) had the capacity to produce 46,000 tons of dehydrated meat a year. The expected acute shortage of refrigerated shipping did not occur, and so it did not become necessary to supply domestic consumers in Britain with dehydrated meat. This was issued instead to the Forces in Britain and the Middle East and to manufacturers of meat products.

The process can achieve a great saving in both weight and bulk, and hence of shipping space. An average fore-quarter of beef weighing 150 lb. can be reduced by boning and dehydrating so that it weighs only 44 lb. when packed for transport. (The equivalent in corned beef is 120 lb.)

Institute of Oceanography tests Underwater TV Equipment

Britain's Institute of Oceanography has installed underwater television equipment in its research ship, *Discovery II*, which is lighter and more easily handled than that used for salvage work in H.M.S. *Reclaim*. (This equipment and the results it gave were described by W. R. Stamp in DISCOVERY, Sept. 1952, pp. 293–6.)

The new camera was equipped with $2\frac{1}{2}$ in. f/1·9 and $1\frac{1}{2}$ in. f/2 lenses, either of which could be selected underwater by the remotely controlled turret. A split-field stereoscopic attachment could be fitted to the $1\frac{1}{2}$ in. lens, to provide right and left eye pictures side by side on the screen.

The Institute, reporting on the preliminary trials of this equipment, says that the technique can develop into a valuable oceanographical instrument, which confirms the view of Dr. H. Barnes of Millport, who contributed our recent article (DISCOVERY, June 1953, pp. 172–4) on Underwater Television and Marine Research. Successful pictures of the sea floor have been obtained in water up to 80 fathoms, but on the whole the pictures obtained of marine animals are not as good as those which Dr. Barnes secures.

Insect Pests can Gas Themselves

Discussing fumigation techniques for ridding stored grain of insect pests at a recent conference, Mr. G. V. B. Herford

A Scientific Study of Fire Resistance

For ten years or so the Building Research Station of the D.S.I.R. has been testing building structures for fire resistance. Results are now available in the publication entitled *Investigations on Building Fires: Part V, Fire Tests on Structural Elements* (H.M.S.O., 15*s*.).

This includes a set of fire-resistance gradings for several typical forms of construction. The results of over 200 tests follow, in the form of data sheets, which give details of the structural element under test, the temperatures reached at various points within it and its general behaviour when subjected to the standard test.

* * *

The fire resistance of ordinary floors for small houses and flats is dealt with in *Building Research Station Digest*, No. 54 (H.M.S.O., 3*d*.).

80 in. Lens for Television Cameras

A new lens of 80-in. focal length for television cameras is now on loan to the B.B.C. by Marconi's, and was used at the televising of the Ascot meetings in June. Its magnification is twice that of the recent 40-in. lens.

The lens was devised in co-operation with the optical firm of Cox, Hargreaves and Thomson and is based on the Cassegrain reflecting system.

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Liver Extracts, Vitamin B12 and Growth

There has been much speculation about a growth factor present in liver preparations, and the existence of a new vitamin has been postulated. There is, however, considerable evidence to suggest that at least part of the increased growth rate which follows the administration of liver preparations may be due to the vitamin B12 in them.

There are, for example, the results of a recent American experiment showing the effect of this vitamin on apparently well-nourished school children. The details are published in the *Journal of Clinical Nutrition*, and the essential facts are as follows.

Twenty children who showed retarded growth acted as controls, while the two other groups, of 20 and 16 children respectively, were observed before and after treatment with 10 micrograms of vitamin B12 orally each day. In the 36 children who received vitamin B12, 23 showed accelerated growth after the treatment. This average increase in growth—the rates before and after administration of the supplementary vitamins being compared—was significant in the group which received B12 for 16 weeks.

In another study involving 236 children a highly significant response in growth was reported, even when the whole group was used in the analysis; that is, when all of the responses—whether positive, zero or negative—were averaged, there was a sufficient number of positive responses to give an increased rate of growth, for the group as a whole, of 0·244 and 0·067 levels per month.

Commenting on the results of the experiments with vitamin B12 supplements another journal, *Nutrition Review*, has this comment to offer:

"The occurrence of periods of slow rates of growth in children in a well-to-do community is of interest; the long-range significance of the condition is as yet not clear. The role which is played by psychological factors remains to be studied. *Until more critical studies of the effect of vitamin B12 on the growth of school children and their ability to learn are reported, the widespread use of this vitamin as a substance for promoting growth is not justified, and should be discouraged.*"

Spraying Against Slugs

The gardener relies on metaldehyde (usually mixed with bran) to kill slugs, but a more convenient mode of application of this slug-killer needs to be perfected before the chemical can be used for killing this pest on a large scale. Some experiments have been made by B. D. Moreton of the National Agricultural Advisory Service, at Wye in Kent, in which metaldehyde is applied by spraying. He has worked with the following four types of spray material: 0·02% aqueous solution made by shaking metaldehyde with water; solutions of higher concentration prepared by dissolving metaldehyde in methyl alcohol and then mixing with water; suspensions of commercial powdered metaldehyde, further ground and mixed with water containing 0·1% of a spreader; and a suspension of a 25% wettable metaldehyde powder. All the preparations were applied as fine sprays at the rate of 94 ml. per square yard, equivalent to 100 gallons per acre.

Applications equivalent to 1·7 and 2·5 lb. per acre gave a high 'catch' of slugs. Those of 5 lb. gave a slightly, but not significantly, higher 'catch'. Laboratory experiments suggested that, under humid conditions, deposits on soil equivalent to 5 lb. per acre brought about kills of about 90% and survivors did not feed for at least a fortnight. Under the laboratory conditions, a 5 lb. per acre deposit retained its full effectiveness for five days, while a five-day-old deposit of the 1 lb. rate had lost effectiveness.

These results are recorded in *Plant Pathology*, June 1953.

Science in the U.S.A.

The British Commonwealth Scientific Office has produced a review entitled *Science in U.S.A.* (H.M.S.O., 2*s.* 6*d.*), which states that America has increased her financial support for research and development by about 270% in the past decade. It is estimated that $2930 million will be spent on these activities during 1952–3. Pre-war, the Federal Government paid for about 7% of the work done in industry and university, but the current figure is about 40%.

The Federal Government employs directly some 91,000 science and technology graduates; more than half are engineers. 58,000 are employed on research projects. (These figures do not cover the Atomic Energy Commission.)

$350 million will be spent on research in all faculties in universities during the year 1952–3, and more than 80% of this sum will be provided by the Federal Government in the form of grants or contracts.

Nine-tenths of the total expenditure will be on research in the biological and physical sciences including engineering, and one-tenth on the humanities and the social sciences. Educational authorities, anxious to preserve a balance between the arts and the sciences in university post-graduate schools, are reported to be worried by the bias of university research in favour of science and technology. They fear that one result may be a dearth, in ten years' time, of faculty members in the humanities and social science.

Industrial research and development employs about 71,000 persons with university degrees or equivalent qualifications, and some 95,000 technical and non-technical assistants employed. There are about 2800 industrial laboratories, more than half of which have less than ten professional staff. Seven laboratories have staffs of more than 1000 professional workers. Research budgets in industry in normal times (there is an increase under war-time conditions) tend to remain constant at between 6 and 8% of the capital investment on new plant and equipment.

The Slow Development of Nuclear Power: An American View

No rapid development of nuclear plants to produce power at a price competitive with conventional power plants is likely in America in the near future. This view was expressed by M.I.T.'s professor of nuclear engineering, Dr. Manson Benedict, who was responsible for the design of the huge Oak Ridge gaseous diffusion plant for making U235, when he addressed the American Chemical Society recently.

He said there were four main factors delaying U.S. development in this field: technical difficulty, lack of immediate demand, security, and the Atomic Energy Act. He considered that, because the United States depends for survival on its continuing pre-eminence in atomic weapons, and will not need large-scale nuclear power for 25 years or more, there should be no relaxation of security solely to facilitate development of industrial nuclear power. "The time is not ripe for widespread declassification of technical information on atomic energy," he said, but he thought it was vital that private companies should be encouraged to develop nuclear power plants, and the law should be changed to permit them to own patents in this field.

The basic fact, remarked Dr. Benedict, is that in the U.S.A. at the present time there is no project aimed directly at the eventual production of industrial nuclear power from uranium at costs competitive with other fuels; U.S. reactor developments aim instead at plutonium production or power for military vehicles.

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OFFICIAL APPOINTMENTS

ASSISTANT (SCIENTIFIC): The Civil Service Commissioners invite applications for pensionable posts. Applications may be accepted up to 31 December, 1953, but an earlier closing date may be announced either for the competition as a whole or in one or more subjects.

Age at least 17½ and under 26 years of age on 1 January, 1953, with extension for regular service in H.M. Forces, but candidates over 26 with specialised experience may be admitted.

Candidates must produce evidence of having reached a prescribed standard of education, particularly in a science subject and of thorough experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces, covering a minimum of two years in one of the following groups of scientific subjects:

(i) Engineering and physical sciences.
(ii) Chemistry, bio-chemistry and metallurgy.
(iii) Biological sciences.
(iv) General (including geology, meteorology, general work ranging over two or more groups (i) to (iii) and highly skilled work in laboratory crafts such as glass-blowing).

Salary according to age up to 25: £236 at 18 to £363 (men) or £330 (women) at 25 to £500 (men) or £417 (women); somewhat less in provinces. Opportunities for promotion.

Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S.59/53. Application forms should be returned as soon as possible.

VICTORIA UNIVERSITY COLLEGE
(New Zealand)

THE VICTORIA UNIVERSITY COLLEGE COUNCIL proposes shortly to appoint a Professor of Geology, and now invites applications from suitably qualified persons.

Salary will be at the rate of £1500 per annum rising to £1700 per annum by annual increments of £100. The initial salary will be determined according to the qualifications and experience of the appointee. Allowance is made for travelling expenses.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 5 Gordon Square, London, W.C.1. The closing date for the receipt of applications is 1 October, 1953.

EXPERIMENTAL OFFICERS AND ASSISTANT EXPERIMENTAL OFFICERS in various Government Departments. The Civil Service Commissioners invite applications for pensionable posts. Applications may be accepted up to 31 December, 1953, but an earlier closing date may be announced either for the competition as a whole or in one or more subjects. Interviews will generally be held shortly after the receipt of the completed application form.

The posts are divided between following main groups and subjects: (*a*) Mathematical and Physical Sciences, (*b*) Chemistry and Metallurgy, (*c*) Biological Sciences, (*d*) Engineering subjects and (*e*) Miscellaneous (including e.g. Geology, Library and Technical Information Services).

Age Limits: For Experimental Officers, at least 26 and under 31 on 31 December, 1953; for Assistant Experimental Officers at least 18 and under 28 on 31 December, 1953. Extension for regular service in H.M. Forces.

Candidates must have at least one of a number of specified qualifications. Examples are Higher School Certificate, General Certificate of Education, Scottish Leaving Certificate, Scottish Universities Preliminary Examination, Northern Ireland Senior Certificate (all in appropriate subjects and at appropriate levels), Higher National Certificate, University degree. Candidates taking their examinations in 1953 may be admitted. Candidates without such qualifications may be admitted exceptionally on evidence of suitable experience. In general a higher standard of qualification will be looked for in the older candidates than in the younger ones.

Inclusive London salary scales:

Experimental Officer
£681–£838 (men); £586–£707 (women).
Assistant Experimental Officer
£274–£607 (men); £274–£511 (women).

Starting pay according to age up to 26. At 18, £274; at 26, £495 (men) £467 (women). Somewhat lower in provinces.

Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S94–95/53. Completed application forms should be returned as soon as possible.

MINISTRY OF SUPPLY, Research Establishment, SE. London requires PHYSICIST to assist in work involving application of electron microscopy to explosives and metallurgical problems. Qualifications: Higher School Certificate (Science) or equivalent; but higher qualifications, e.g. degree, may be an advantage. Previous experience in electron microscopy not essential but experience involving advanced metallographic techniques required and knowledge of high vacuum techniques and electronics an advantage. Salary within range, Experimental Officer (min. age 26), £681–£838. Women somewhat less. Post unestablished. Application forms from M.L.N.S., Technical & Scientific Register (K), 26 King Street, London, S.W.1, quoting A.93/53/A.

APPOINTMENTS VACANT

RESEARCH ASSISTANT required by established London company for high vacuum evaporation and spluttering techniques. Applicants age 25–35 should have physics degree or equivalent, previous experience in this field preferable. Permanent, progressive, pensionable post. Salary according to first-class ability the company is seeking. Full details to Box No. D1513, Aldridge Press Ltd., 15 Charterhouse Street, London, E.C.1.

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